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PRINTED IN THE UNITED STATES OF AMERICA

Duncan Clark McKeever

1905 - 1959

The brilliant career of Duncan Clark McKeever was terminated violently on the night of October 13, 1959, when a car with faulty brakes driven by a drunken man plowed into him as he stood in the driving rain pouring gasoline into his own automobile.

His death means the loss of a truly independent thinker, not only in the field of orthopaedic surgery, but also in the philosophic fields of medical economics and social reform. He held strong convictions. He could not endure bigotry or indecision. Practices based only on convention and not on good scientific judgment he regarded as intolerable. He enjoyed all men of purpose, and he both learned continuously from them and gave of himself unsparingly to them.

Dr. McKeever was born on September 13, 1905, in Valley Falls, Kansas. He attended Westport High School and Junior College in Kansas City, Missouri. Aside from 50 dollars given him by his parents for his first year of medical school, he completed his education at the University of Kansas Medical School in 1929 by his own efforts. His internship was patterned by belonging to the Naval Reserve. He spent 1 year at the U.S. Naval Hospital in Brooklyn and 3 years at the Great Lakes Naval Station near Chicago. After completing his naval service, he accepted a residency in pathology at St. Luke's Hospital in Kansas City, Missouri, the orthopaedic fortress of Dr. Frank Dickson and Dr. Rex Diveley. These men soon converted him from postmortems to the Lane technic. After 3 years' preceptorship he became associated with them and remained with them until 1939, when he went to Houston, Texas, to establish his own practice.

Being in the Naval Reserve, he was called

to active duty in 1941. His principal assignments were as chief of orthopaedics of the Long Beach Naval Hospital and, later, the area hospital at Honolulu. He was discharged from the Service in 1945 with the rank of captain. Because of confusion with Francis McKeever at Academy meetings, he liked to identify himself as "the Navy McKeever." He would tell a perplexed caller, "You have the wrong McKeever: I'm the Navy one; the Army McKeever's first name is Francis "

Dr. McKeever was certified in orthopaedic surgery in 1937. He was a fellow of the American Academy of Orthopaedic Surgeons, the Clinical Orthopaedic Society, the American College of Surgeons and the American Medical Association. He was president of the Association of Bone and Joint Surgeons. He was also a member of the Association of American Physicians and Surgeons, the Houston Orthopaedic Club and the Texas Orthopaedic Association. He was co-founder of the Spectators' Correspondence Club and the American Society of Clinical Hypnosis. At the time of his death he was president of the American Fracture Association.

He was a member of the orthopaedic staff of Memorial Hospital, St. Joseph's Hospital, Herman Hospital and St. Luke's Hospital, all of Houston, Texas. He was past chief of the orthopaedic section of Memorial Hospital; past president of the medical staff of Memorial Hospital; chief of staff of the Texas Elks Crippled Children's Hospital, Ottine, Texas; consultant for the queries and answers section of the *Journal of the American Medical Association*, and a director of the American Motor League (Safety).

Dr. McKeever had great aptitude as a mechanic, being one of the first orthopaedists to train in the use of power tools. He studied engineering principles, particularly in the fields of stresses and strains, which in turn he applied to bone surgery. He described several operations, such as: his bunion operation; a modification for excision of semilunar cartilages; an operation for interdigital neuromas; and prosthetic replacements for the hip, the patella, the tibial plateau and the acetabulum.

He was a pioneer in bowed-tendon surgery in the racehorse. This enabled animals that might otherwise have been destroyed to come back as winners. He traveled far and wide both as student and teacher in his own and allied professions. He had many friends south of the Border. He learned Spanish after he was 50 and was host to many Latin-American surgeons, who frequently spent several weeks in his home while observing and assisting him at operations and on rounds. Termination of this little-known phase of his generosity deprives the United States of a most popular ambassador.

In addition to his writings, he produced scientific movies for the Audiovisual Program at his own expense. Principal subjects were reconstruction of badly damaged knee joints; mechanical stresses of lumbosacral stabilization; interdigital neuroma; and the knee cartilage (this film was entitled *Take It Out Backwards*).

We extend our sympathy to his wife, Dorothy Grant McKeever, whom he married in 1934, and to three sons, who plan to follow in their father's footsteps. The oldest, twins, 24, Rex and Dick, are sophomores at Jefferson Medical School; and John, the youngest, 21, is a premedic at Wabash College. The McKeever family was united by a variety of mutual interests, among which were turkey-, deer- and duck-hunting, fishing, a goat ranch, and communication by ham radio while the children were away at school

All who knew Dr. McKeever are appalled and saddened by his senseless and untimely death. As an admirer put it: "Duncan wasn't through working yet."

E.N K ; G.P.; I H.S.

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GENERAL ORTHOPAEDICS

Section III

ITEMS

1

Allen B. Kanavel (1874-1938)

Sumner L. Koch, M.D.*

Of the many men who have played an important part in the surgical history of his time, none was more loved, respected and admired, both by the surgical profession at large and by those closely associated with him, than Allen B. Kanavel.

Allen B. Kanavel was born September 2, 1874, the son of a Methodist minister, in a little town in central Kansas. He came to Chicago in 1891 to enter Northwestern University. After graduating from the College of Liberal Arts he entered the medical school and graduated with honors with the class of 1899. Immediately afterward, as he once said, through the aid of an aunt who had more faith in him than good judgment, he went to Vienna and spent 6 months in graduate study before entering upon his internship at the Cook County Hospital. Immediately after its completion he became associated with the department of surgery at Northwestern University Medical School.

Early in his surgical career Dr. Kanavel was struck by the haphazard treatment accorded patients with severe infections of the hand. This led to a painstaking study of the anatomy of the hand by a method not previously attempted—the forcible injection into its tendon sheaths and fascial spaces of an opaque material and the careful observation of the route of spread and extension of the injected material. He learned that this extension followed a definite and constant pattern and that it would be possible to predict with exactness the direction and the extent of spread of an infectious process. He showed further how it would be possible to incise and drain the primary site of infection and the paths along which the infection extended with minimum damage to the vital structures of the hand. These studies, pursued over nearly 10 years, were incorporated in 1912 in a monograph entitled *Infections of the Hand,* which today is regarded as the basis of our knowledge of the adequate and efficient care of this common and often serious condition. However, Dr. Kanavel's interest was not confined to infections of the hand. He was initiated into surgical practice at a time when most men were general surgeons and the day of the specialist had hardly dawned. While he was an able and skilled general surgeon, it would be more correct to describe him as a specialist in many fields of surgery. His early association with Dr. Franklin Martin afforded him the opportunity to acquire a wide experience and develop an excellent technic in gynecologic surgery.

Dr. Kanavel also became keenly interested in neurologic surgery; he developed an original method of approaching the pituitary fossa through the nose and skillfully performed operations on the trigeminal nerve for the relief of tic douloureux and on the spinal cord for pathologic conditions involving the spinal pathways. He prepared the section on neurologic surgery in Ochsner's *System of Surgery.* With Dr. Charles Elliott he studied the problem of congenital hemolytic icterus and was the first in America to remove the spleen as the effective therapeutic procedure in this, in 1915, often unrecog-

* *Chicago, Ill.*

nized disease. It seemed as though everyone at Northwestern University or Wesley Hospital who was confronted with some unusual or difficult problem turned to him for help. Whether it was a man with a serious burn requiring plastic work, a woman desperately ill from thyroid intoxication, a man with long-continued drainage from an empyema cavity, or a child with a congenital deformity of face, lip or hand, Dr. Kanavel seemed to come first to the mind of the attending physician as the one best qualified to give expert help.

Dr. Kanavel was quite as much at home in the field of abdominal surgery as in that of the extremities, and, though he never "operated by the clock," if he ever chose to "put on steam" it was difficult for his assistants to keep pace with him. He could carry out routine procedures with unusual dexterity and lightning speed, but, when working about the axillary vessels in performing a radical operation for carcinoma of the breast or removing a congenital cyst close to the carotid sheath, he was patience and gentleness personified.

Once, when operating before a large group of visiting surgeons on a patient with a huge retrosternal goiter, an intrathoracic vein suddenly gave way, with profuse and alarming hemorrhage. Quickly he passed a finger behind the sternum, stopped the bleeding by pressure and then, by sense of touch alone, placed a hemostat on the torn vessel hidden in the thorax. Dr. Charles Mayo said afterward that it was the coolest performance under fire that he had ever witnessed. On another occasion, after watching him remove, through the posterior pharyngeal wall, a bullet that had lodged just below the base of the brain, between the occiput and the atlas, of a 15-year-old boy, Sir Berkeley Moynihan said that, if ever he needed to have an unusually difficult operation performed on himself, he hoped that Dr. Kanavel would be there to do it.

In spite of his acknowledged ability and success in the field of surgery, there was absolutely nothing of the egotist about him. Often he told the story of a distinguished visitor from New York who, in his Chicago hotel, was seized suddenly with abdominal pain. Dr. Kanavel was called to see him, as were three other well-known Chicago surgeons. Eventually Dr. Kanavel was asked to operate upon him, and the patient made a successful and uneventful recovery. Just before the patient left the hospital Dr. Kanavel said to the man's secretary, "I am interested to know why I was chosen to operate upon Mr. Blank." At this point he would always remark with amusement and delight, "I thought, of course, he would say, 'We could not help but sense your surgical skill,' or 'Your surgical reputation extends far beyond Chicago.' " Instead came the reply, "Well, Mr. Blank himself made the decision. He said anyone as homely as Dr. Kanavel must surely be honest."

Dr. Kanavel left behind him many evidences of his outstanding activities and his wide interests in the field of surgery. The world-wide reputation of the surgical journal *Surgery, Gynecology and Obstetrics* speaks eloquently of the time and the effort that he expended on it, as associate editor and editor, from the day of its beginning to the day of his death. It was always close to his heart. He felt that it was a vital force in making better surgeons and in helping the practitioners of surgery in America, particularly those outside the teaching centers, to keep pace with the rapid changes constantly going on in surgical practice.

Beside the office of *Surgery, Gynecology and Obstetrics* is the beautiful Murphy Memorial Building and the home of the American College of Surgeons. From its inception Dr. Kanavel was closely associated with Dr. Franklin H. Martin in the development of the College and helped constantly to direct its activities. This, too, he felt was a definite and vital organization, not imposed upon the medical profession but growing up within it, that could help to raise and maintain high standards of surgical practice and hospital

service in America and so bring lasting benefit to suffering humanity.

His monograph *Infections of the Hand*, his best-known contribution to surgical progress, was widely recognized and acclaimed, not only in America, but throughout the world. It would be difficult to estimate how many hands have been saved and restored to useful function because of his original contributions on the pathogenesis, the course and the correct surgical treatment of acute, spreading infections of the hand. No less important than his contribution to the subject of infections of the hand were his many papers on the treatment of injuries of the covering tissues of the hand, of tendons and nerves and of congenital and acquired deformities, and his contributions in the field of neurosurgery and abdominal surgery.

A report of the removal of pituitary tumors by an intranasal route, described in 1909 and 1910, antedated by many years a method that is being utilized today in the removal of the pituitary gland for malignant disease.

A report on tuberculous tenosynovitis of the hand, published in 1923, was the first authoritative paper on this subject in American surgical literature. A paper on splinting and physiotherapy in infections of the hand, published in 1924, called attention to the importance of the position of function and led to the abandonment by thoughtful surgeons of the crippling banjo splint and of the too-frequent tendency to immobilize injured and infected hands in complete extension for prolonged periods of time. A report of 29 cases of Dupuytren's contraction with detailed anatomic studies of the palmar fascia, published in 1929, was regarded so highly that parts of it were published verbatim under another name and in a different surgical journal. An exhaustive study of congenital malformations of the hand, published in two successive numbers of the *Archives of Surgery* in 1932, remains the outstanding contribution on this subject in American surgical literature.

DR. ALLEN B. KANAVEL

Less tangible, but not of lesser importance, of Kanavel's contributions were the stimulus and the determination that he inspired in his students and associates to study, to contribute to medical progress and to carry out the best possible type of surgical practice. As with all great teachers, he lives on in those who studied under him and learned something of the kindliness, the humility and the idealism that were his outstanding characteristics.

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Section I

THE HAND: PART II

2

Surgical Anatomy of the Hand

H. MINOR NICHOLS, M.D.

Surgery of the hand requires a detailed knowledge of anatomy. The surgeon's dissection in normal tissues should be rapid and effortless, leaving ample time for excision of pathologic tissues or repair of tendons, nerves or bones. While dissecting-room specimens provide the usual source of anatomic knowledge, most cadaver hands are of such poor quality that their usefulness is limited. Freshly amputated surgical specimens are much better.

To provide a set of charts having a three-dimensional quality, the plates in this chapter were made from layer dissections of a fresh specimen. Accuracy of color and proportion was ensured by photographing each dissection To guide the surgeon, the structures are shown as they occur in each layer, much like an architect's plans of each floor of a house. Some variation in the dissection of the digits was made to show in detail the tendon mechanism

SKIN

Landmarks. The skin of the hand fits tightly enough to reveal many of the underlying structures. Beneath the dorsal skin it is easy to see (and palpate) the extensor tendons, as well as the metacarpals and the wrist joint. The volar skin is well marked by flexion creases that lie opposite joints or attach the distal palm to the fingers. The muscles forming the thenar and the hypothenar eminences can be seen and palpated when tensed, and in thin individuals the tensed flexor tendons are palpable. Other palpable landmarks are the radial and the ulnar styloids marking the wrist joint and the greater multangular and pisiform indicating the location of the carpal tunnel. On the front, the skin is well anchored by many vertical fibers, which extend through the superficial fat to the heavy palmar aponeurosis beneath. On the dorsum, it is loose and elastic, stretching when the fingers are flexed.

DEEP FASCIA

When the skin and the superficial fascia are removed, the deep fascia (Figs. 1 & 2; Plate 1) is revealed. Perforating vessels and cutaneous nerves are encountered at this level as they penetrate the deep fascia and lie between it and the skin. Dorsally, the sensory branches of the radial and the ulnar nerves come to the surface an inch or so above the wrist and then branch out in a variable pattern to cover the back of the hand. Volarly, two small branches of the median and the ulnar nerves appear similarly to supply the base of the palm. In the fingers, digital branches emerge from beneath the palmar fascia to supply the skin on each side of each digit. These latter nerves are most important for sensation. The *ulnar nerve and artery* emerge from beneath the volar carpal ligament at the wrist and pass beneath the palmaris brevis and under the medial edge of the palmar fascia into the hand. Elsewhere, the deep fascia thoroughly covers the structures beneath.

The palmar fascia and the transverse carpal ligaments are specialized thickenings

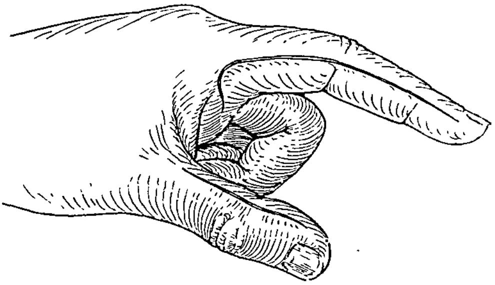


FIG. 3. Mid-lateral incision in the index finger with short palmar extension. Mid-lateral thumb incision (usually made on radial side of thumb).

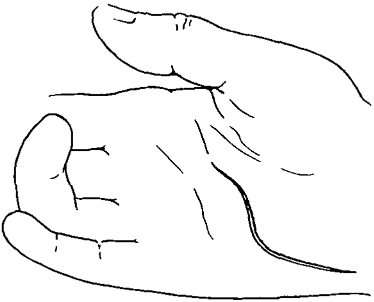


FIG. 4. Transverse palmar incision with extension down mid-lateral border of hand for exposure of motor branch of ulnar nerve.

of the deep fascia. The transverse carpal ligament roofs over the carpal tunnel, being attached to the bony prominences of the pisiform and the hook of the hamate medially and the greater multangular and the navicular laterally. Posteriorly, a thickening called the dorsal carpal ligament bridges over the extensor tendons at the wrist and binds each functional tendon unit into a separate groove. The palmar fascia is a triangular ligament that is continuous with the transverse carpal ligament; it extends distally to cover the area over the metacarpals in the palm Heavy perpendicular bands attach it to the metacarpals, and prolongations of it run out into the digits. By a series of arches over the structures beneath, it protects and supports tendons, neurovascular bundles and lumbrical muscles. It blends with the fascia over the thenar and the hypothenar muscles. By numerous bands to the skin it attaches the palmar skin to the underlying bony framework of the hand. The palmar fascia is intimately connected to the flexor tendon sheaths, which extend from the metacarpophalangeal joints to the distal phalanges. These sheaths are thickened along the phalanges and thinned out at the joints.

DEEP STRUCTURES

(Figs. 1 & 2; Plates 2 & 3)

Between the enveloping fascia and the underlying bones one finds the muscles, tendons, nerves and vessels There are about

An Atlas of Surgical Anatomy of the Hand

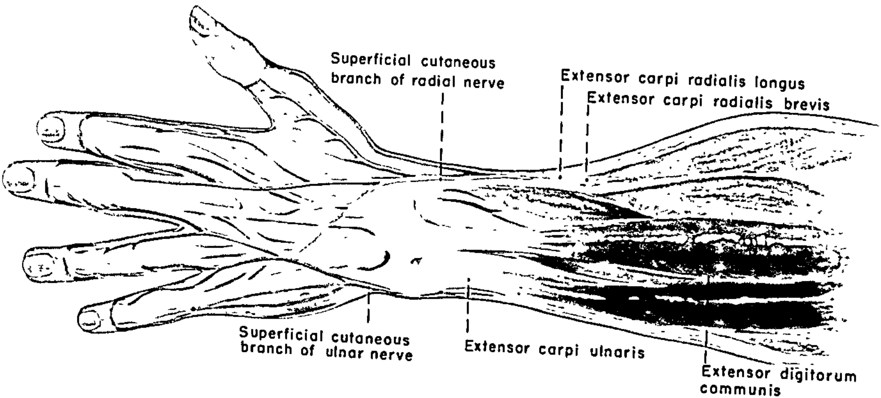


FIG. 1.—Dorsum of hand and forearm. *Plate I*, skin removed, exposing deep fascia and cutaneous nerves.

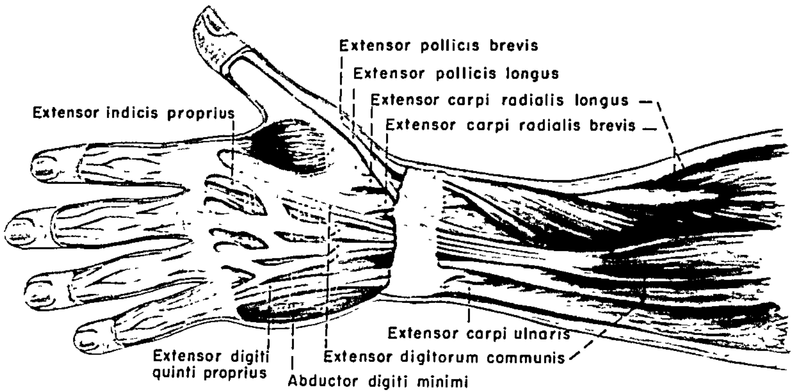


FIG. 1 *(cont.)*.—*Plate II,* deep fascia removed, exposing tendons and muscles.

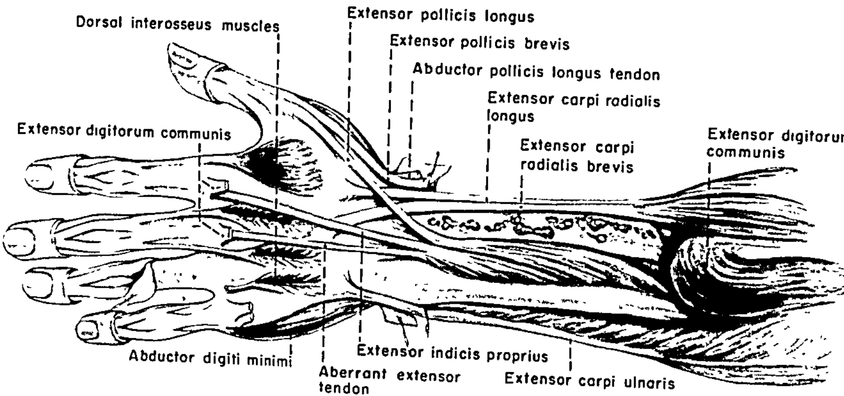


FIG. 1 *(cont.)*.—*Plate III*, superficial muscles and tendons removed, exposing deep muscles, radius and ulna.

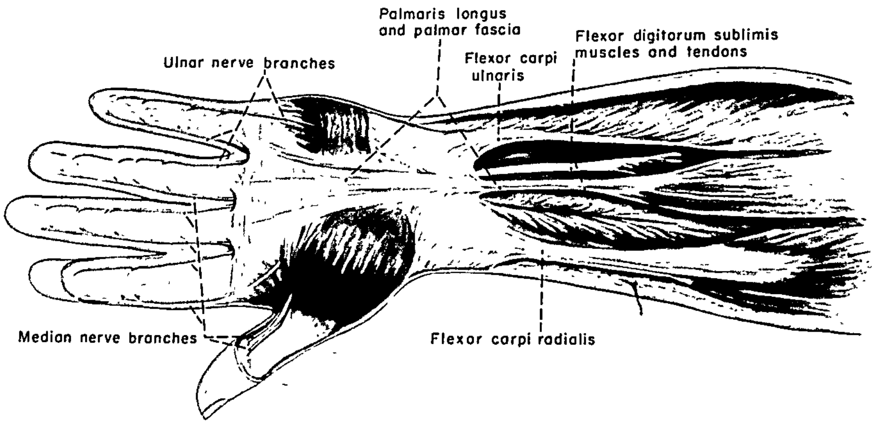


FIG. 2—Volar surface of hand and forearm. *Plate I,* skin removed, exposing palmar fascia and digital nerves. Superficial muscles and tendons show through thin fascia.

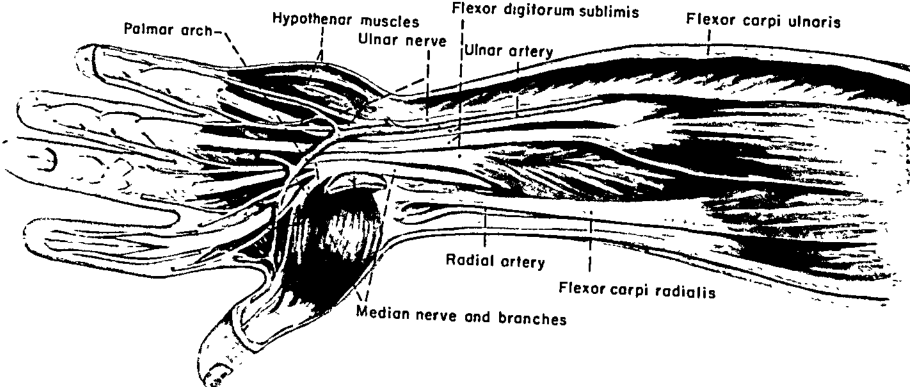


FIG. 2 *(cont.)*.—*Plate II*, transverse carpal ligament cut and deep fascia of the forearm, palmaris longus and palmar fascia removed, exposing superficial tendons, ulnar nerve and median nerve.

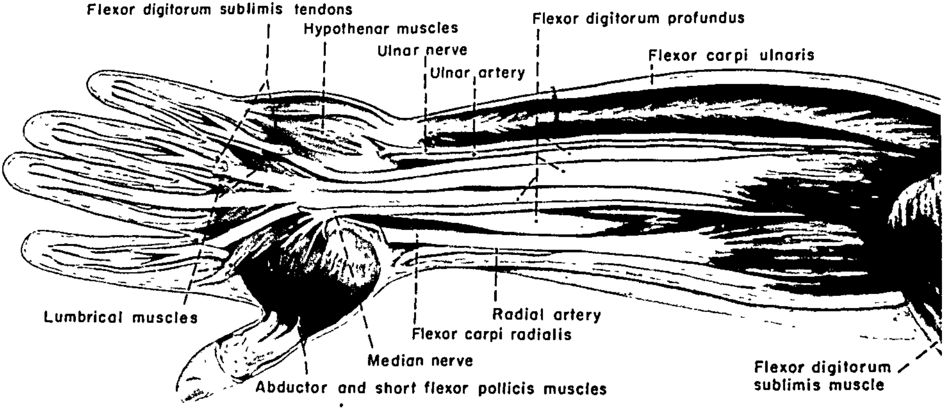


FIG. 2 *(cont.)*.—*Plate III,* sublimis muscles and nerves and tendons removed from palm, exposing profundus muscles and tendons with lumbricales.

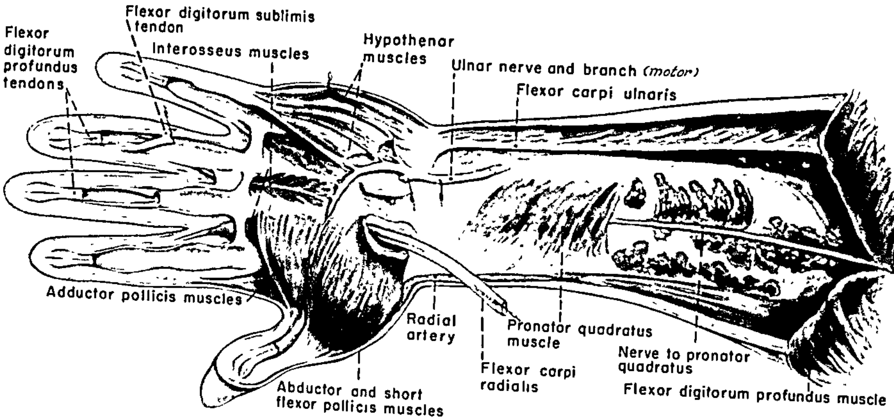


FIG. 2 *(cont.)*.—*Plate IV*, deep tendons removed, showing tendon sheaths, radius and ulna, pronator quadratus and deep branch of ulnar nerve supplying muscles in palm.

a dozen musculotendinous units on either surface of the forearm. Forearm muscles are all pinnate or bipinnate, with a central core of tendon extending for a long distance above the musculotendinous junction. The musculotendinous juncture of each tendon is far enough away from the wrist so that nothing but tendon slides under the volar or the dorsal carpal ligament. Dorsally, the superficial tendons have the longer excursion, and with correspondingly longer exposed tendons, whereas volarly the deep tendons have the longer excursions and longer tendons.

From the surgeon's point of view, the proximal two thirds of the forearm is mostly muscular and the distal one third mostly tendinous. The principal nerves and vessels are on the volar surface of the forearm, lying between the superficial and the deep muscles and emerging near the wrist to lie superficially to the tendons. (This relationship is well illustrated in Fig. 2; Plates 2 & 3.)

With the forearm held in mid-pronation and supination, the origin and the insertion of the flexor and the extensor muscles are properly aligned and the relationships made less confusing. In this position the extensor muscles arising from the external condyle and the flexor muscles arising from the internal condyle can be visualized as they spread out over their respective forearm surfaces, and their tendons can be followed in a direct line to their respective wrist and digit insertions. On both dorsal and volar aspects the tendons that move the fingers lie between the tendons that move the wrist.

Dorsal Muscles and Tendons

(Plate 1; Figs. 1-3)

Dorsally, the structures are more spread out and the layers less confusing than volarly. The dorsal muscles arise superficially from a common tendon of origin at the external epicondyle and deeply from osseous origins on the radius and the ulna, and the interosseous membrane.

Anatomy texts class the wrist extensor muscles with the extensors of the fingers in the superficial group of muscles. This classification is confusing because the tendons of the wrist extensors lie deep to extensors of the thumb at the wrist. (Fig. 1, Plate 3, shows a more rational division for surgical anatomy.) At the wrist and on the back of the hand the tendons are all at about the same depth except that the thumb extensors and abductors at the wrist pass over the radial wrist extensor. The proprius muscle of the index finger and the long extensor of the thumb are the lowest and the deepest structures on the dorsum of the forearm. Where the extensor tendons pass under the dorsal carpal ligament each one is provided with a small separate sheath or bursa. The extensor tendons on the dorsum of the hand lie in the soft areolar tissues beneath the skin and superficial fascia, making them simple to repair, graft or transfer.

The dorsum of the fingers is covered by an aponeurosis that extends the finger joints. The insertion of the extensor tendons is into the base of this aponeurosis over the metacarpophalangeal joints. The aponeurosis is triangular, with the apex inserting into the distal phalanx and the base receiving the insertions of the interossei and the lumbricales at its angles and the common extensor tendons at its thickened center. When the extensor tendon is tensed, the entire aponeurosis slides proximally, and the extensor tendon exerts a direct pull on the dorsal articulating lip of the middle phalanx extending this joint, and as this joint straightens the pull is transmitted by the lateral bands to the distal joint. The interossei then act to abduct or adduct the fingers and to prevent hyperextension of the metacarpophalangeal joints. Meanwhile, the lumbrical muscles draw the flexor tendons distally and aid the interossei in extending the fingers. When the extensor tendons are relaxed, the entire aponeurosis slides distally, allowing the interossei to flex the metacarpophalangeal joints and through their lateral bands to extend the interphalangeal joints. The complexities of

this mechanism have been exaggerated in numerous descriptions because of the interaction of the intrinsic and the extrinsic muscles of the hand and the bizarre positions assumed when the hand is out of balance. When the interossei are paralyzed in a recent ulnar nerve lesion, the fingers can be made to extend properly simply by placing the dorsum of the hand on a flat surface. The more advanced states of these conditions (claw hand, for example) are a summation of imbalance of musculature plus secondary joint changes, muscle contractures, etc. (See also the paragraph on intrinsic muscles.)

Volar Structures

(Plate 2; Figs. 1-4)

The superficial muscles of the front of the forearm have their origin from a common tendon on the medial epicondyle of the humerus and adjacent ligaments and osseous structures of the elbow. This group includes the pronator teres, the wrist flexors and the flexor digitorum sublimis. The flexor carpi radialis crosses the forearm in its upper third and then lies along the medial border of the radius. Its tendon runs through a separate fibro-osseous canal external to the carpal tunnel to insert in the base of the second and the third metacarpals. The flexor carpi ulnaris lies along the medial border of the ulna. At the wrist its tendon inserts into the pisiform bone, from which ligamentous fibers go to the carpus and the fifth metacarpal. The flexors of the digits lie between these wrist flexors. The sublimis muscles arise from the internal epicondyle. Their tendons pass through the carpal tunnel at the wrist, fan out in the hand and attach to *the sides of the middle phalanges* of the fingers. At the wrist the tendons of the long and the ring fingers lie superficial to those of the index and the little fingers. Each sublimis tendon is split over the proximal phalanx to allow the profundus to pass through it.

The deep muscles include the flexor digitorum profundus and the flexor pollicis longus muscles. They arise from the upper two thirds of the radius and the ulna, and their tendons lie in the deepest layer, being situated on top of the pronator quadratus, the bones of the carpus (passing through the carpal tunnel) and then the metacarpals in the hand. They insert on the distal phalanges of the digits. At the wrist the digital flexors enter bursal sacs that extend into the hand, and in each digit there is a separate tendon sheath extending from the metacarpal phalangeal joint to the distal joint.

There are twenty intrinsic muscles in the hand. Five thenar muscles position the thumb, four hypothenar muscles position the little finger, four dorsal interosseous muscles abduct the fingers, and three volar interosseous muscles adduct the fingers. There are also four lumbrical muscles. The combined function of these muscles is important, especially in fine motions. They coordinate flexion and extension, cup the palm and rotate the thumb, similar to the action of the boom of a crane. When damaged, usually they can be repaired or excised; when paralyzed, their functions can be replaced by certain substitution operations.

Nerves and Vessels

There are three nerves on the volar surface of the forearm: ulnar, radial and median. The ulnar artery accompanies the ulnar nerve; the radial artery, the radial nerve; and at times a median artery accompanies the median nerve. In the proximal muscular part of the forearm the nerves and the arteries lie between the superficial and the deep layers of muscles.

The ulnar nerve lies in a groove between the trochlea and the olecranon on the medial side of the elbow. It enters the forearm by passing between the heads of the flexor carpi ulnaris muscle and follows down the course of its muscle lying lateral to it. At the wrist it emerges from under cover of the flexor carpi ulnaris tendon and passes beneath the volar carpal ligament and the palmaris brevis muscle into the palm. Branches at the elbow sup-

ply the flexor carpi ulnaris and the ulnar half of the flexor profundus muscle. There are no further branches until it passes the pisiform bone. Here it divides into a deep motor branch and superficial sensory branch. The deep branch of the ulnar nerve penetrates through the origin of the hypothenar muscles arising from the lateral side of the hook of the hamate and then passes transversely across the volar surface of the metacarpals. By individual twigs it supplies the hypothenar muscles, all the interossei, the short adductor and the ulnar head of the flexor pollicis brevis, as well as the two ulnar lumbrical muscles. As it crosses the palm, it accompanies the deep palmar arch formed by the deep branches of the radial and the ulnar arteries. The superficial branch of the ulnar nerve passes beneath the palmaris brevis vessel and then divides into two common volar digital branches, one of which supplies the fourth cleft and the other the ulnar side of the little finger.

The ulnar artery arises from the brachial just below the bend of the elbow. It passes beneath the bellies of the superficial flexor muscles and crosses obliquely beneath the median nerve on top of the profundus muscles to join the ulnar nerve in the upper third of the forearm. It accompanies the ulnar nerve throughout the rest of its course, lying superficial to it in the forearm and medial to it in the wrist.

The radial nerve, which is both a dorsal and a volar structure, passes through the origin of the brachioradialis muscle at the elbow and divides into a deep motor branch and superficial sensory branch. The deep motor branch winds round the neck of the radius, passing through the supinator muscle, which it supplies, and then continuing down between the deep and the superficial layers of the extensor muscles. Large branches given off near the elbow supply all the muscles arising from the external epicondyle. A smaller branch runs down beneath these muscles to supply the extensors and the abductors of the thumb and the extensor indicis proprius muscles. The sensory branch of the radial nerve lies just beneath the brachioradialis throughout most of the forearm. About two or three inches above the wrist it turns dorsally, passing beneath the brachioradialis tendon and piercing the fascia to supply the skin on the back of the thumb and the index finger.

The radial artery arises from the brachial opposite the ulnar artery. The radial artery accompanies the superficial branch of the radial nerve throughout most of the forearm, lying on top of the pronator teres and the flexor pollicis longus. In the lower part of the forearm, it lies between the tendons of the flexor carpi radialis and the brachioradialis. At the wrist it passes beneath the long abductor and extensor tendons of the thumb and appears briefly on the dorsum of the first metacarpal before it penetrates the first dorsal interosseous muscle at the apex of the first cleft. Then it passes deep to all the structures in the palm as the deep palmar arch. Here it accompanies the deep motor branch of the ulnar nerve.

The median nerve enters the forearm with the brachial artery passing beneath the lacertus fibrosis in close proximity to the biceps tendon. At the elbow it crosses the ulnar artery, passes between the two heads of the pronator teres, thence down the middle of the forearm between the deep and the superficial muscles. In the distal tendinous portion of the forearm the median nerve emerges from beneath the sublimis tendons and comes to lie, first, radial to these tendons, then at the wrist and in the hand on top of them. It passes through the carpal tunnel in this position. A deep muscular branch at the elbow is given off that branches further to supply all the muscles arising from the median epicondyle except those two supplied by the ulnar nerve. Branches also go to the profundus and the pronator quadratus muscles. The main branch runs through the forearm without branching until it emerges from the carpal tunnel. The nerve here becomes flattened and

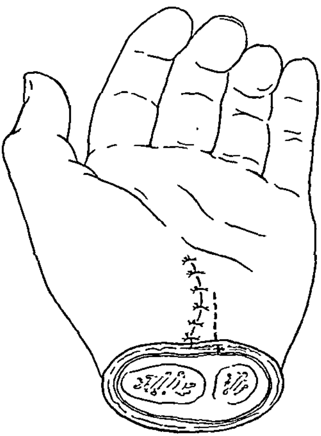
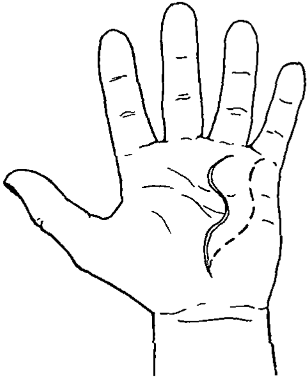


FIG. 5. Offset between skin incision and ligamentary incision (broken line) to expose carpal canal.



splits into two portions. The lateral porti gives off the motor branch to the thenar mu cles, and the sensory digital branches to t thumb and the radial side of the index fing The median portion divides into two comm volar digital nerves that run to the seco and the third clefts.

Immediately beneath the palmar fascia the proximal part of the palm lie the supe ficial palmar arch and its common volar di ital branches. The sensory branches of t median and the ulnar nerves pass beneath t vessels in the palm, and here the neurovasc lar bundles lie against the lumbrical muscl They then pass through the lumbrical cana to the fingers with the lumbrical tendons.

INCISIONS

Surgical incisions in the hand should ta advantage of lines where the skin does n *move to avoid contracture,* should be plann so that kindly healing will occur, and shoul give the required exposure. A mid-lateral i cision in a digit (Fig. 3) corresponds to t *mid-line incision in the abdomen.* It giv good exposure, it can be extended, and i healing it does not interfere with function. A incision along a crease in the palm likewi does not jeopardize blood supply to the fla and heals without contracture. Mid-later incisions in the palm (Fig. 4) are occasionall useful but do not give good exposure unle they are used as extensions of palmar-creas incisions. Whenever an incision crosses joint on moving skin, a zigzag should be mad to reduce scar contracture. Palmar skin wit its specialized whorles and padding an abundant pacinian corpuscles should not b sacrificed unnecessarily, as any replacemen is inferior to it.

In operations on the hand and the forearn it is often advantageous to dissect the ski away from the deep fascia before doing fur-

FIG 6. Incisions for Dupuytren's contracture. *Broken line for maximum* involvement of little finger. Solid line for maximum involvement of ring finger.

ther surgery. The flaps thus created are well supplied with arteries and veins; perforating vessels encountered are ligated at this level, and cutaneous nerves that penetrate the deep fascia and lie beneath it and the skin can be protected. Surgical attacks on the deep structures of the hand invariably require opening the deep fascia. Where this fascia is thin and acts only as an enveloping membrane, as on the forearm and the dorsum of the hand, it may be split; or, if scarred, it may be excised, and generally it can be ignored in wound closure. Small holes in it give rise to muscle hernias that are corrected by making the hole larger. When a tendon-supporting ligament (transverse or dorsal carpal ligament) is incised for exposure, it is best to detach it laterally from one of its bony insertions. In this maneuver the incisions should be staggered so that the fascial incision will lie under an intact flap of skin instead of under the skin incision (Fig. 5). In many operations in the palm, a partial palmar fasciectomy will give better exposure of the nerves and the tendons beneath and allow the healing tendons to lie against the more mobile skin.

The most extensive incision commonly used to uncover the palm is made in the operation for Dupuytren's contracture. The author prefers a linear serpentine incision that follows natural creases in the palm lying over the area of maximum pathology (Fig. 6). This incision necessarily varies from case to case, and an exact description of it is difficult. It combines wide exposure with minimum wound complications or postoperative contractures It is not suitable for tendon or nerve repairs and should not be used for them. A long excision for exposure of the median nerve and/or tendons in the palm, the carpal canal and the forearm regions can be made by incising along the thenar crease, turning somewhat radially at the base of the thumb, then curving toward the ulnar side of the wrist to connect with a serpentine in the forearm (Fig 7). The transverse carpal ligament should be incised so that the skin incision does not correspond with the ligamentary incision (Fig. 5). This incision gives excellent exposure of all the tendons and the median nerve here and is designed to protect the tendons during healing. The palmar portion of this incision lies directly over the tendons to the index finger and, with a little undermining, gives good exposure of the tendons of the long finger. For exposure of the tendons of the ring and the little fingers in the palm, an incision is made along a faint crease line that occurs along the fourth cleft.

Incisions in the distal palm should be transverse, either paralleling or lying in the lines of the flexion creases (Fig. 7). In op-

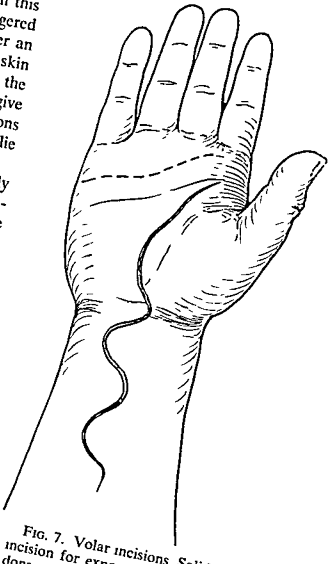


Fig. 7. Volar incisions. Solid line incision for exposure of flexor tendons and median nerve. Broken line, transverse incision for lesions of the distal palm.

erations on the fingers and the thumb, midlateral incisions give the best approach to flexor tendons and nerves. A short transverse incision may be used for excision of small ganglia or other small tumors. In any transverse incision in the digits, the digital nerves should be protected. At times the surgeon will desire to expose the structures in the thenar eminence. By making a long incision mid-laterally over the proximal phalanx and metacarpal of the thumb, a flap of skin and subcutaneous tissue can be turned up, and the entire thenar musculature, together with nerves and tendons, will be exposed. This incision is quite satisfactory for nerve or tendon repairs, and, if careful attention is paid to hemostasis, kindly healing is assured.

The motor branch of the median nerve should be protected carefully in any operation on the palm of the hand or the carpal tunnel. The author prefers always to dissect it out and identify it when doing a palmar fasciectomy for Dupuytren's contracture, as it has often been damaged in this operation. When the motor branch of the ulnar nerve is damaged in a deep saw cut or in a puncture wound on the ulnar side of the hand, it can be dissected out and repaired through an incision along the proximal transverse palmar crease turning down the ulnar border of the palm at the metacarpal level (Fig. 4). The skin and the subcutaneous tissues are raised as a flap and turned back to expose completely the origin of the hypothenar muscles from the hook of the hamate and the origin of the deep and the superficial branches of the ulnar nerve. The muscle origins are detached, and the nerve then can be followed down into the depth of the palm.

Dorsal Incisions

Dorsal incisions on the hand may be linear, transverse or serpentine, depending on the operator's preference and the exposure required. A jog is made in the incision when-

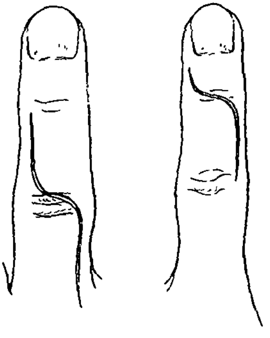


Fig. 8. Incisions for exposure of extensor tendon insertions over middle and distal joints.

Fig 9. Dorsal incision for exposure of extensor tendons, wrist ganglia, etc.

ever a joint is passed (Fig. 8), and sharp corners are avoided. The result is a variant of the serpentine, or Z, that prevents contracture. In the forearm, a mid-lateral incision is perfectly safe, but a long volar or dorsal mid-line incision is apt to keloid. This can be avoided by applying the serpentine principle (Fig. 9).

The wrist extensors and the brachioradialis are the first muscle bellies encountered at the external epicondyle. In operations on the head of the radius, one will encounter these muscle bellies as well as the underlying supinator muscles and the motor branch of the radial nerve that passes through the supinator and supplies the extensor muscles. The main muscular branches to the extensor muscles are given off somewhat distal to the supinator. In approaches to the upper end of the shaft of the radius, these branches can be picked up between the deep and the superficial groups of muscles.

Chirurgia Anatomic del Mano

Summario in Interlingua

Le prime medietate del texto describe le aspectos essential del anatomia chirurgic del mano e antebracio in terminos simplificate al beneficio del operante. Hypersimplification es evitate. Omne aspectos de importantia es mentionate, ben que le plus succinctemente possibile.

Un serie de illustrationes in color, facite ab dissectiones de frescamente amputate specimens chirurgic, accompania le texto.

Le secunde medietate describe le incisiones chirurgic usate per le autor. Iste incisiones es illustrate per appropriate designos linear basate super casos real.

Ben que il es a pena possibile reclamar originalitate in un tractato de anatomia, le methodo de presentation usate in iste manuscripto es nove.

3

The Place of Flexor Tendon Grafts in the Repair of Flexor Tendon Injuries to the Hand

D. C. ROBERTSON, M.D.*

Division of the flexor tendons of the fingers and the thumb within the sheath is an injury that often is repaired now by a tendon graft. This is a change from the past, when primary suture was the only method of management. The frequent bad results of primary suture have forced the adoption of tendon-graft repair, sometimes in unsuitable cases and often with poor results. Enough time has passed since the introduction of this operation to gain experience and judgment. The early enthusiasm must now be tempered by this experience if poor results are not to continue in spite of improved technics.

The careful selection of cases and knowledge of what can be accomplished by a tendon-graft repair will improve the results of these operations. It must also be remembered that there is still a place for primary repair, and in certain circumstances it may give a better result than a tendon graft.

First of all, some basic principles must be stated. These have been learned through experience. No tendon repair of any kind should be attempted when the wound is "untidy" or the injury is several hours old. This is even more important in cases in which there are concomitant injuries, such as fractures of the phalanges, loss of skin cover in the finger, or damage to one of the joints of the finger. However, associated nerve injury may accompany a tendon repair without detracting from the result. With these principles in mind it is clear that most cases of division of the flexor tendons will not be suitable for immediate repair.

In the case of an old injury there are also certain principles to be followed. No tendon repair should be considered if there is limitation of passive movement in the proximal interphalangeal joint. The original wound must be well healed, and the tissues of the finger must be free of swelling and be soft and supple. Division of both digital nerves is a contraindication. In our experience, the anesthetic finger is a poor operative risk; it is likely to be stiff and to be already the seat of atrophy and sensitivity to cold. Unless the nerve injury can be repaired, a tendon repair will also fail.

The foregoing states a very broad principle: the conditions required for a tendon repair of any kind in either a fresh injury or an old one are the same. For a repair to be considered, the wound in a fresh case must be the same as the surgical wound at operation —clean, recent and incised In addition, the finger must be free of other injuries or disabilities. When the injury is recent and these conditions are not fulfilled, the necessary steps must be taken to achieve them, and this means elective repair at a later date. If the conditions are fulfilled in a recent injury, either a tendon-graft repair or primary suture may be done.

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We must now consider the reasons for success or failure in both primary suture and tendon-graft repair. Primary tendon suture may fail for many reasons. The injured tendon swells while healing, filling the sheath and adhering to it. The tendon suture is adjacent to the skin wound, and the two may adhere. It may be necessary to put up the finger in acute flexion to relieve tension. In this position adhesions and the development of joint stiffness may ruin the result, as the ensuing stiff finger is flexed far beyond the position of function. Any movement that may be obtained in such a position is not useful.

Repair by tendon graft avoids all these troubles. The tendon graft is small in diameter; when it swells, it does not fill tightly the space prepared for it The anastomoses of the graft to the profundus tendon proximally and to the terminal phalanx distally are not adjacent to a wound. The graft may be made long enough for the relief of tension to be achieved without immobilizing the finger in acute flexion. The position of function will be the center about which any movement obtained will play. However, tendon-graft repair has troubles of its own. The graft is, of course, avascular. It may adhere throughout its length, perhaps because of an attempt by the surrounding tissues to vascularize it. This is the great difficulty. There are others, but they can be avoided in a large measure by careful attention to detail before, during and after operation

With these points in mind, cases of divided flexor tendons in the hand should be considered

Let us first consider the tendons divided in the palm of the hand, proximal to the metacarpophalangeal joint. If the division is so placed that when the finger is extended the distal cut end is still proximal to the crease between the finger and the palm, suture is probably the best choice of treatment. The tendon suture in this position is less likely to adhere to surrounding structures than is a tendon graft from palm to terminal phalanx. Furthermore, if adhesions are formed, they may be far less extensive due to the limited exposure required for this repair.

When the flexor tendons are cut in the palm with the fingers acutely flexed, the distal cut end is retracted, on extension of the finger, to a position under the proximal crease of the finger. This is a poor place to have an anastomosis, as it always adheres and spoils the result. Here a tendon graft is preferable, as there is no swollen anastomosis in the tendon trying to play freely through the tunnel, which is so narrow at this point.

Next to be considered is injury in which the profundus tendon alone is divided distal to the insertion of the sublimis. The patient cannot flex the terminal phalanx. This, in itself, is not the only disability. The terminal segment of the finger collapses into extension whenever pinch is attempted. It is this lack of stability that is the disability. In an injury such as this it must be recognized that a tendon-graft repair would be very radical treatment indeed. This patient has active flexion at the proximal interphalangeal joint, but after a tendon-graft repair, even if the sublimis is retained, there may be a net loss of flexion in the proximal interphalangeal joint. However, it will provide stability as the adherent graft is really tenodesis. Therefore, the patient may have traded good active flexion in the proximal interphalangeal joint for stability at the terminal joint. Under these conditions a primary suture is advisable in a fresh injury. If it succeeds, the result is excellent; if it fails because of adhesions, the result is still good, as the joint is secured in good position. If the injury is old, a tenodesis using the distal cut end of the profundus tendon is a simple and satisfactory way of stabilizing the distal joint.

When the division of the profundus tendon is near the insertion into the terminal phalanx—that is, not more than ¾ inch—the proximal tendon may be pulled down and attached to the terminal phalanx after discarding the distal portion.

So far the discussion has concerned those cases in which a tendon-graft repair may be unwise. The tendon division found to be between the proximal crease of the finger and the insertion of the sublimis when the finger is extended at operation will require a tendon-graft repair. Fear of infection because of the duration of the wound or injury, or its condition, nearly always dictates elective repair. Elective repair is also dictated by concomitant injuries to bone or joint, by extensive superficial lacerations, and by division of both digital nerves. All these conditions must be repaired first, and this is true of fresh and old injuries. Indeed, the old injury, with the finger stiff in acute flexion after a primary repair that has stuck, will require operation for the removal of the adherent tendon so that the finger may be mobilized. It may be wise to do nothing more than this and to await the return of good passive movement before attempting any repair.

TECHNIC

The technic of tendon-graft repair has been well described many times. Here the author mentions a few points that he considers will help to improve results.

Although the palmaris longus frequently is used, the author much prefers the long extensors of the toes as donors. These tendons are long enough and are surrounded by paratenon. Their removal leaves no unsightly scar or disability. They are taken through the incision shown in Figure 1. The exposure in the palm and the finger is obtained through the incisions shown in Figure 2. In the dissection of the finger, care should be taken to remove all the tendon sheath. The object of the operation is not to replace a tendon in the

FIG. 1 Incision for removal of extensor tendon of toe for tendon graft

sheath but to substitute a tendon sliding in areolar tissue.

The method of anastomosis between the end of the profundus and the graft should be such that as little as possible cut tendon is left exposed. The method illustrated in Figures 3 and 4 has been used by the author for some years. It has the advantage of being able to produce a strong union with little bulk. The attachment of the graft to the terminal phalanx is also important. It should be well distal to the terminal joint. The author's preference is illustrated in Figure 3. The profundus tendon is cut off flush with the bone, and the end of the graft is applied to the phalanx and heals there with a No. 00 silk suture as shown. This suture is brought through the nail with a curved needle on each side of the phalanx, thus embracing it, and is tied over a button. It is removed in 4 weeks, the removal presenting no difficulty.

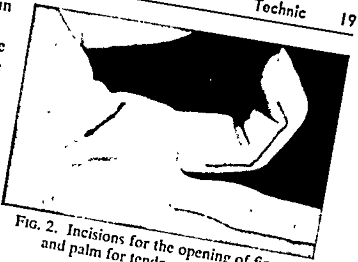

FIG. 2. Incisions for the opening of finger and palm for tendon-graft repair.

After closure of the wound a cast is applied with the wrist in flexion and the finger in the position of function. It is removed after 3 weeks, and gentle movement is begun. In this we follow the practice of Mason and Allen.[3] It has been suggested, and indeed practiced by Pulvertaft,[5] that this immobilization is not necessary. He has suggested that if the wrist

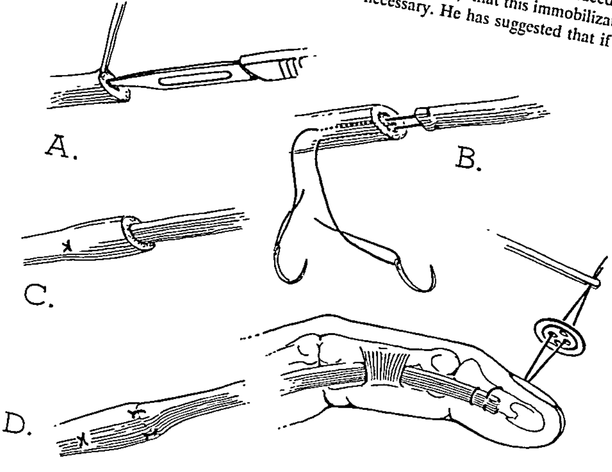

FIG. 3. Details of anastomosis of tendon graft.

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is maintained in acute flexion, there is not sufficient flexor power remaining to disrupt the suture lines of the tendon graft. However, this experience has not been universally confirmed; it may result in disruption about the tenth or the eleventh day.

When the cast has been removed, physiotherapy is begun. It is far more important to train the patient to do what is required than to provide a physiotherapist. The postoperative period must be the responsibility of the surgeon himself. There should be some active

FIG. 4. Completed anastomosis of graft to profundus tendon.

FIG 5. Completed tendon graft in finger, showing preservation of a retinaculum to prevent bowstringing.

movement when the cast is removed. This will increase with time and persistent exercise. When there is no active movement at all 1 week after removal of the cast, there never will be any; continuing physiotherapy is useless. Physiotherapy can only increase a range of movement when there is some movement to begin with.

SUMMARY

The conditions under which a tendon-graft repair may be carried out depend upon the location of the injury. At the time of operation the injured finger must be normal in all other respects: good passive movement must be present, good sensation must have returned, and all swelling and induration must have subsided. These conditions may require a long period of time between injury and elective repair.

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Le Rolo de Graffos de Tendine Flexori in le Reparo de Vulnerationes de Tendine Flexori del Mano

Summario in Interlingua

Le autor discute le varie typos de vulnere que produce lesiones del tendines flexori del mano. Es signalate que vulneres contaminate e vulneres presentate plus que alicun horas post lor occurrentia non tolera un reparo primari de tendines. Tal vulneres require disbridamento de forma appropriate e clausion con satis tempore pro avantiar le processo curative al restablimento de mobilitate articular in le digitos vulnerate ante que un reparo elective es interprendite. In le experientia del autor, nulle reparo de tendines ha unquam succedite in casos de vulneration associate con perdita de pelle digital o con fracturas o con lesiones articular. Tal casos require le reparo del lesiones associate e un intervallo de tempore pro lor convalescentia ante que un elective reparo de tendine pote esser interprendite. Le reparo de un traumatisation de tendine flexori in le mano non pote unquam succeder si illo es interprendite ante que un gamma complete de movimentos passive ha essite restablite. In plus, le presente articulo delinea in detalio le technica usate per le autor in reparo per graffo de tendine. Es delineate e illustrate le avantages del typo telescopic de anastomose inter le graffo e le termino secate del tendine profunde.

4

Exposing Fractures of the Proximal Phalanx of the Finger Longitudinally Through the Dorsal Extensor Apparatus

DONALD R. PRATT, M.D.*

Fractures of the phalanges of the fingers result in both considerable temporary and permanent disability. The proximal phalanges of the fingers are fractured much more frequently than the middle or even the distal phalanges. These fractures may result from either direct or indirect trauma; they may be simple or compound, but generally they are comminuted. Although there may be little or no displacement, deformity with considerable displacement is typical when the proximal phalanx is fractured.

Because of the resultant relationship of the muscle balance of the long extensor and flexor muscles of the fingers and the intrinsic muscles of the hand (the interossei and the lumbricals), fractures of the proximal phalanx generally result in marked deformity.

The deformity in shaft fractures of proximal phalanges is a volar angulation or bowing, resulting from flexion of the proximal fragment by the taut interossei and lumbrical muscles flexing the proximal finger joint by their transverse fibers and a dorsiflexion of the distal bony fragment from the pull on the dorsal aponeurosis through its lateral bands by the intrinsic muscles and its central slip by the long extensor tendon. This deformity may be complicated by lateral angulation and even rotation displacement when comminution is present.

* San Francisco, Calif.

Specific principles must be followed for the adequate treatment of finger fractures.* Several methods may be used in fractures of the proximal phalanges of the fingers. In undisplaced simple fractures, splinting wrist, hand and involved finger in the position of function generally suffices. When there is displacement or deformity, some type of Böhler or Watson-Jones splinting is commonly employed. This consists of reduction of the deformity and maintenance of the position with some type of skin or pulp immobilization. Thus the desired position of the fracture, with the wrist in dorsiflexion and the finger in a semiflexed position of function, is maintained following manipulation. This method usually is adequate. However, it must be remembered that it is not without associated problems. Specifically, traction and undue local points of pressure should be avoided; proper rotary position and angulation of the finger joints must be maintained, and the judicious use of some type of occasional exercise of the fingertip must be carried out.

When the finger deformity is severe or the fracture is compound, surgical intervention invariably is required. Accurate reduction of the fracture and maintenance of the desired position can best be achieved by internal fixa-

* Bunnell, Sterling: Surgery of the Hand, ed 3, Philadelphia, Lippincott, 1956.

tion with Kirschner wires. This does not add any complicating factors, because frequently these fractures are already compound. If the fracture can be exposed through the wound, reduction and positioning of the bony fragments can generally be accomplished most satisfactorily by the following method: A Kirschner wire is inserted retrograde through the fracture site distally. The fracture then is reduced, and adequate positioning of the fragments is obtained and maintained by passing the Kirschner wire proximally across the fracture site well into the proximal bony fragment.*

In those cases in which the simple fracture is associated with considerable deformity, angulation or rotation, or the fracture is compound and not adequately exposed through the wound, or the fracture is associated with tendon injury, the use of open reduction and Kirschner wires has been found to be of tremendous advantage in the treatment of the fracture deformity. It permits accurate reduction of the fracture, satisfactory immobilization of the fracture in the reduced position, maintenance of the finger position without an external plaster splint, which generally encumbers the rest of the hand and the digits, and early mobilization of the fingers so as to minimize joint stiffness and ensure early exercise of the associated repaired tendons.

* Pratt, D. R., Bunnell, S., and Howard, L. D.: Mallet-finger, classification and methods of treatment, Am. J. Surg 93:573-579, 1957.

The metacarpophalangeal joint area frequently is exposed in surgical capsulectomy. The convenient procedure has been to expose the extensor hood over the knuckle and to excise the collateral ligaments on each side of the extensor apparatus. For some time Dr. L. D. Howard, Jr., of San Francisco, has used the dorsal exposure of the metacarpophalangeal area by splitting the extensor apparatus longitudinally over the knuckle and retracting the extensor tendon laterally, thus providing excellent exposure of the capsule and the collateral ligaments of the metacarpophalangeal joint. The slit in the extensor tendon then is approximated with a continuous single monofilament No. 34 stainless-steel wire suture or with interrupted buried braided Fagersta wire sutures, restoring continuity of the extensor apparatus and permitting early motion without disability to the joint or the extensor mechanism.

Excellent exposure of a fractured proximal phalanx can be obtained by this dorsal longitudinal splitting of the extensor tendon.

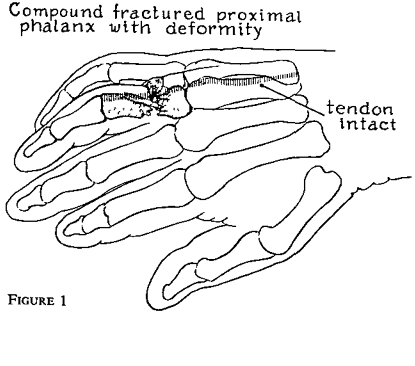

FIGURE 1

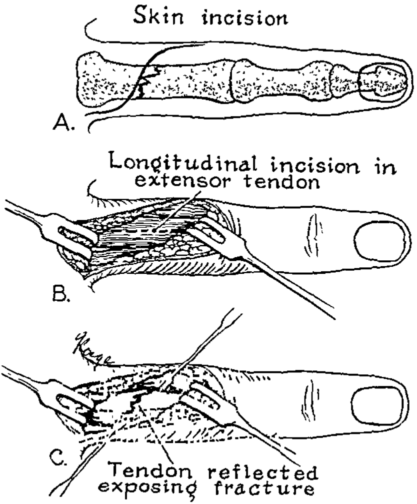

FIG. 2. *Diagrammatic stages in the exposure of the dorsum of the finger with a fractured proximal phalanx.*

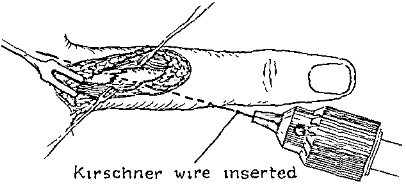

FIG. 3. Diagram of insertion of Kirschner wire across the fracture site.

The lateral or oblique approach to the proximal-finger segment is difficult and offers inadequate exposure. *The use of the dorsal* approach to the proximal segment of the finger was used recently in 17 cases of fractured digits and proved adequate in all. The extensor tendon is split longitudinally, exposing *the shaft of the proximal phalanx and* either the metacarpophalangeal or the proximal interphalangeal joints of the finger, or both. Then the fracture can be reduced under direct vision and the position held, while pinning, either directly or retrograde through *the fracture site, achieving reduction of the* fracture and firm fixation. By placing one of the Kirschner-wire pins axially and one obliquely, rotational deformity is avoided, and stable internal fixation is ensured. Next, *the extensor tendon is approximated with* several buried interrupted fine braided wire sutures, and the skin is closed with interrupted monofilament stainless-steel sutures

No plaster support is necessary, and ordinarily early gentle exercise can be instituted to minimize soft-tissue swelling and finger-joint stiffness. Under local anesthesia in the office, the pins are cut off just beneath the skin to obviate local irritation and yet to permit easy removal upon healing of the fracture.

DISCUSSION

In this series of 17 cases, 8 simple fractures were treated. The fracture sites were exposed through curved incisions across the

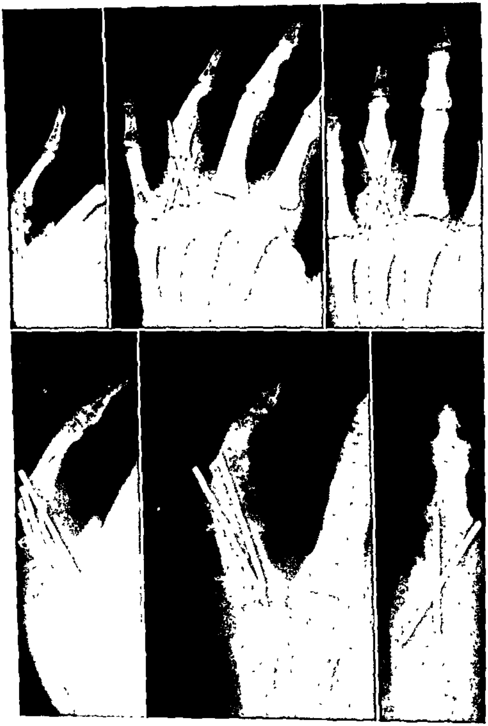

FIG. 4. (*Top*) Fracture fixed with Kirschner wires. Note interrupted fine wire sutures in the extensor tendon beneath the dorsal skin. (*Bottom*) Oblique fracture of proximal phalanx pinned with Kirschner wires; wire tendon sutures.

dorsum of the proximal segment of the finger, longitudinal splitting of the extensor apparatus providing adequate exposure and satisfactory fixation of the fracture with Kirschner wires. Minimal swelling was encountered, and early motion was instituted.

The other 9 cases were compound fractures. Tendon injuries were present in 7 of them, necessitating associated primary tendon suture. With satisfactory fixation of the fracture, early mobilization of the repaired tendons could be carried out. In 3 of the compound fractures, modified approaches through the extensor apparatus were carried out because of the nature of the original compound wound. However, in the other cases the described operative exposure longitudinally through the extensor apparatus provided excellent exposure of the fractured phalanx without undue soft-tissue trauma. Sixty per cent of the patients were back at some type of light work within 3 weeks, materially reducing the temporary disability.

CONCLUSION

In cases of simple and compound fractures of the proximal phalanges of the fingers, internal fixation has proved a definite therapeutic adjunct. The use of the dorsal approach, with longitudinal exposure through the dorsal extensor tendon, provides a most satisfactory exposure to the fractured proximal phalanx with no appreciable additional trauma to the soft tissues of the finger. This method adds a minimum of trauma, permits most effectual reduction and maintenance of position, obviates external splinting, allows early mobilization, especially in the cases with tendon injury, and minimizes both temporary and permanent disability.

In this series of 17 cases there has been no wound infection. In 1 case, local irritation at one of the pins required its removal earlier than was originally anticipated but did not affect the ultimate healing of the fracture. In 1 case in this series, the question of possible nonunion or delayed union was encountered 4 weeks after reduction. By removing the oblique pin, and with compression along the axial pin, any difficulty was obviated, and early union of the fracture was accomplished.

It is believed that this series demonstrates the advantages of exposure of the proximal phalanx of the fingers through a longitudinal incision in the extensor apparatus in treating fractures of the proximal phalanges.

Le Exposition de Fracturas del Phalange Proximal del Digito, per Accesso Longitudinal a Transverso le Apparato Extensori Dorsal

Summario in Interlingua

In tractar fracturas del diaphyse del phalanges proximal del digitos, simple o complicate e con grados plus o minus marcate de displaciamento, le exposition del sito del fractura es effectuate le plus satisfactorimente per medio de un incision curvate al dorso del digito e un fission longitudinal in le longe tendine extensori. Iste exposition del fragmentos del fractura permitte mobilisation, correction de deformitates, e fixation directe con filo metallic de Kirschner. Le methodo a usar in le exposition es presentate in detalio, con attention special prestate al desiderato de reducer al minimo le disturbation del function del tendines e de effectuar le prompte mobilisation del digito in question. Viste que le majoritate de tal sever fracturas es complicate, le exposition per le methodo describite non adde ulle hasardo al problema del reduction e del fixation interne. Un serie de 17 casos ha essite tractate per medio de iste methodo de tractamento. Le resultatos esseva excellente.

5

Transposition of the Index Finger To Replace the Middle Finger

ROBERT E. CARROLL, M.D.*

A fundamental procedure in reconstruction of the hand is the transposition of digits. This usually implies a transfer of the metacarpal and the phalanges along with the attached tendons, nerves and vascular supply. The formation of a thumb by digital transposition has been widely discussed. Doubtless this procedure is of primary importance in the reconstruction of an injured hand. However, the shifting of an index finger to replace the third finger follows that closely in importance. This technic has not been dealt with adequately in the literature. A useful method for such a transposition is discussed in the following pages.

In World War II, when much hand reconstruction had to be done, there was no available outline for replacing the middle finger by the index finger. Independently, surgeons engaged in reconstruction of the hand were able to work out the steps necessary to make this transfer. The author finds reference to this only occasionally in the literature.[2,5] In Bunnell's and Slocum's texts,[1,6] which evolved from the experience of the last war, this procedure is not documented as fully as its importance deserves.

UNITS OF FUNCTION IN THE HAND

Function of the hand has been discussed and described frequently. In brief, the author considers function to be composed of three units. The thumb is the valuable prehensile digit of the grasping unit. Because of the almost imperceptible motion of the carpometacarpal joint of the index and the middle fingers, these two digits are the unit of power. They transmit the impact of force in a direct blow. These digits are the firm opposing post to the pinch of the thumb. The third unit might be called the feathering unit. The fourth and the fifth digits are of this group. Because of their mobility at the carpometacarpal joint, there is a range of motion that allows great modification in the position of objects held by the first two units. To give a maximum degree of function, no deformity of a single unit that impedes coordination should be present.

The four fingers or digits two, three, four and five together form a cup in function. Moreover, they are the opposing wall to the mittenlike action of pinch, hold or grasp. A break in this wall can leave a deformity that decreases the function of the hand as a whole. One major loss is amputation of the third finger to a level that decreases function.[3] According to Furlong,[4] loss of more than the entire distal and middle phalanges of the third digit markedly deforms the function of the hand. The gap in the grasp permits small objects to fall through the hole. Frequently the short stump projects from the fist and receives a constant traumatizing. The index finger drifts across the gap with angulation at the metacarpophalangeal joint. In such a case pain at this joint has been a presenting symptom. Amputation at the metacarpophalangeal joint to leave a broad

* New York, N. Y.

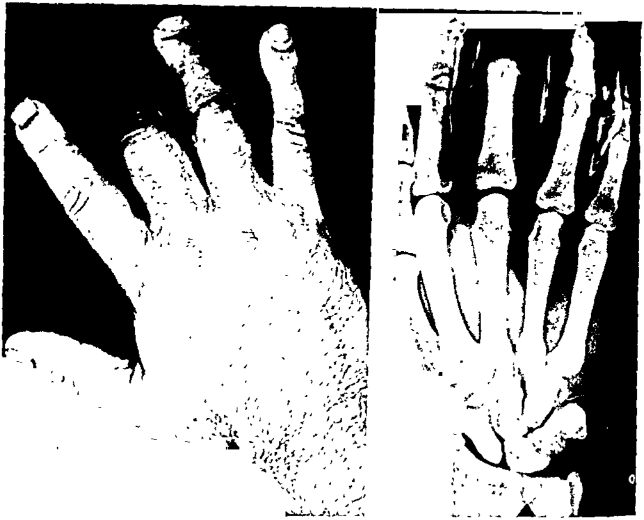

FIG. 1. Amputation through the proximal interphalangeal joint of the third digit left this patient with a severely deformed hand. The stump projected from his fist, and small objects fell through his grasp.

palm for a workingman is more fancy than fact. The majority of patients in the study under discussion here were in occupations considered to be heavy manually.

INDICATION FOR TRANSPOSITION

When the third digit is damaged to the extent that amputation must occur at a site proximal to the distal quarter of the proximal phalanx, function of the finger and also of the entire hand is diminished. The author believes that transposition of the index finger to replace the third finger restores maximum function of the hand It is also gratifying to note that the cosmetic appearance is vastly improved.

The many problems of a workingman with a deforming amputation site of the third digit can be summarized by a typical case history:

A young plumber, 23 years of age, had previously received a crushing injury to the distal phalanx of his third finger. As a result, the finger was amputated at the proximal interphalangeal joint. Although he continued to do the same work, the protruding stump of the third finger was bumped constantly. Several small lacerations had become infected. Since this was his right and dominant hand, understandably the patient became less anxious to use it in situations of potential trauma. Then, while installing pumping machinery, the tender protruding stump of the third digit was struck by a sharp metal corner, which caused the patient to pull the hand back sharply. This loosened a casting that lacerated the third, the fourth and the fifth fingers. It was at this stage that he was first seen by the author (Fig.1).

The right hand showed healing lacerations of the dorsum of the fourth and the fifth digits. The stump of the third digit was healing as well. An amputation had been completed previously at the proximal interphalangeal joint. In closing the fist to grasp, the stump of the third digit protruded noticeably from the hand. Upon questioning, the patient remarked that small objects fell through his fingers. This happened especially in taking change from his pockets.

The index ray was transposed to replace the third ray by operation. In 6 weeks the cast was removed and light activity was encouraged. By the third month the patient was back on the job, straining at heavy wrenches and pipe-cutting dies. After 6 years his grip is as powerful as before his transposition. Small objects are handled easily Furthermore, the appearance of the hand is better (Fig. 2).

CLINICAL MATERIAL

The study reported here is based on 26 patients on whom the author operated personally, as well as 17 patients who underwent operation by other surgeons* at the author's instigation. No patient has been included who was followed for less than 1 year. The first patient underwent operation in 1946.

PROCEDURE

In this operation it is best to drape the whole hand free in order to appreciate the relationship of all digits throughout the procedure. A tourniquet should be used to ensure a clear field. The operative incision is longitudinal on the dorsum of the hand over the space between the second and the third metacarpals (Fig. 3). The distal portion may be extended in a racquet line to

* Dr. Irving Mauer and Dr. Arthur Friedman, of U. S Public Health Service Hospital, Staten Island, N. Y.; Dr. Sigmund Chessid, U. S. Veterans Administration Hospital, Brooklyn, N. Y.; Dr. Baker Huff, U. S. Naval Hospital, St. Albans, N. Y.; Dr. Everett C. Bragg, New York, N. Y.; and Dr. J. P Warter, Westfield, N. J.

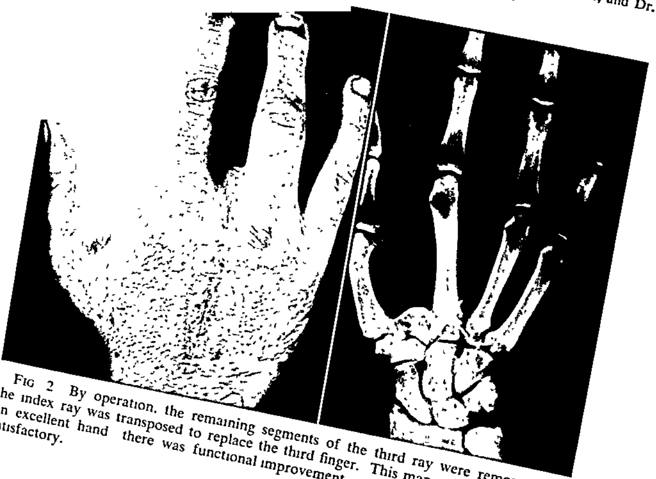

Fig 2 By operation. the remaining segments of the third ray were removed, and the index ray was transposed to replace the third finger. This man, a laborer, obtained an excellent hand there was functional improvement, and the appearance was more satisfactory.

include a residual stump of phalanx, scar tissue or neuroma. The incision is carried proximally to the base of the metacarpals. The bony prominence is easily palpable in this region. The extensor digitorum communis tendon to the third finger is divided longitudinally and allowed to retract. Beneath this, one can easily see the shaft of the third metacarpal with the adjacent bellies of the dorsal interosseous muscles.

A longitudinal incision is made through the periosteum of the third metacarpal. Then the bone is stripped clean of soft tissue subperiosteally. By means of a drill and an osteotome or a power saw, the third metacarpal is divided transversely at the very base, where the flare is apparent (Fig. 4, *left*). Thus it is easier to grasp the metacarpal and strip it from its bed. In so doing, it is easily shelled from the transverse metacarpal ligament without damage to the ligament.

Through the same incision, the shaft of the second (index) metacarpal may be seen. An incision in the periosteum is made from the metacarpophalangeal capsule proximally to the base of the metacarpal. The metacarpophalangeal joint is not opened in any way. By subperiosteal dissection, the origin of the first dorsal interosseous muscle is elevated from the shaft. Should it be found later that more play is needed in the transposition, the origin of the second dorsal interosseous muscle on the shaft of the index metacarpal may also be elevated. Usually this is not necessary. At the base of the index metacarpal, an osteotomy is done to divide the shaft and free the index ray for transposition (Fig. 4, *right*). Restriction in moving the ray now may be adjusted.

At this point the periosteal tube of the third metacarpal should be closed with interrupted sutures. If it is considered to be necessary, the transverse metacarpal ligament may be reefed by a silk suture to approximate more firmly the index and the fourth rays. The shaft of the second metacarpal then is

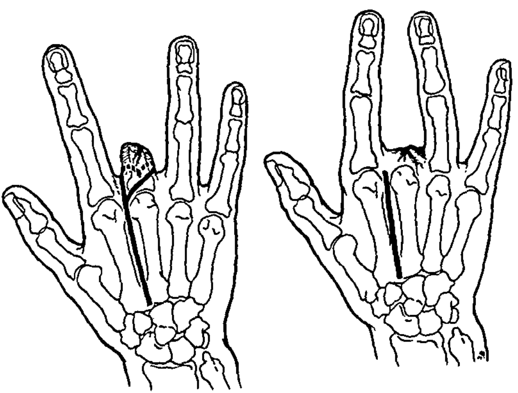

FIG. 3. The incision is made on the dorsum of the hand between the second and the third metacarpal shafts. If a stump of the third finger remains, it may be removed by extending the incision.

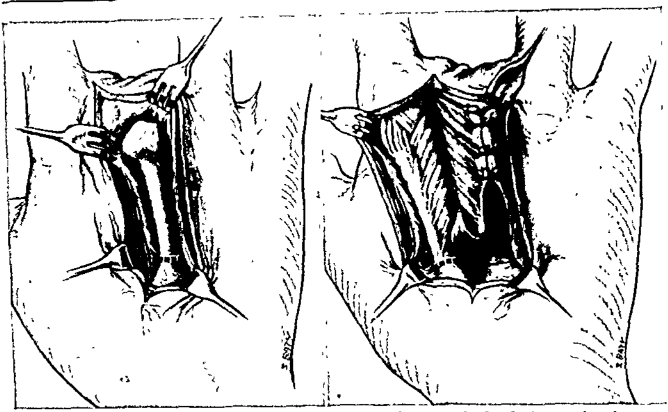

FIG. 4. (*Left*) The shaft of the third metacarpal is stripped of soft tissue subperiosteally. At the base, the metacarpal is divided and removed from the wound. (*Right*) Through the same incision, the shaft of the index finger is stripped of soft tissue on the radial aspect, and the bone is divided at the base. The tube of the periosteum from the third metacarpal then is closed.

placed on the base of the third metacarpal. Next, two Kirschner wires are passed across the arthrodesis site to hold the ray securely in the new position (Fig. 5). Care must be taken to see that the transposed ray is aligned properly with the functional axis of the hand. No further fixation is needed for the interosseous muscle bellies. One or two sutures are placed in the divided extensor tendon. The subcuticular layers and skin are closed in the usual manner. A plaster gauntlet is applied to the hand in the position of function. This is carried only to the metacarpal heads distally so that early finger motion may be obtained This cast remains in place until it is found that firm union has taken place in the metacarpal arthrodesis site. Usually, the cast is removed after 6 to 8 weeks for roentgenographic examination.

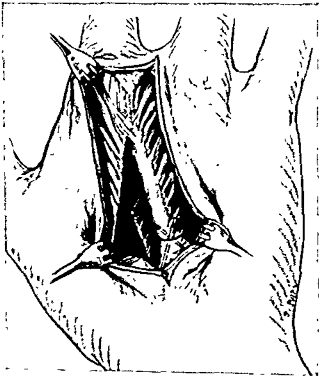

FIG. 5. The index ray may be transposed easily to the position of the middle finger. By fixation with a Kirschner wire, the osteotomy site is maintained securely.

Discussion of Procedure

Often questions are asked about the technic; therefore, it seems worth while to con-

include a residual stump of phalanx, scar tissue or neuroma. The incision is carried proximally to the base of the metacarpals. The bony prominence is easily palpable in this region. The extensor digitorum communis tendon to the third finger is divided longitudinally and allowed to retract. Beneath this, one can easily see the shaft of the third metacarpal with the adjacent bellies of the dorsal interosseous muscles.

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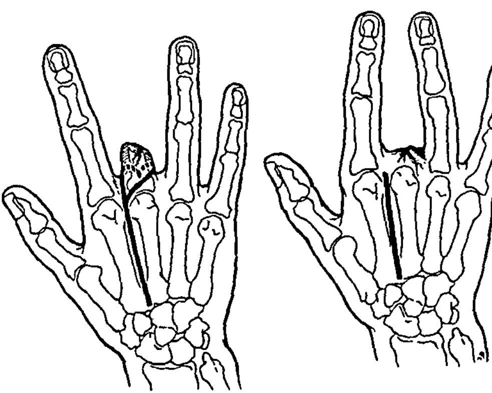

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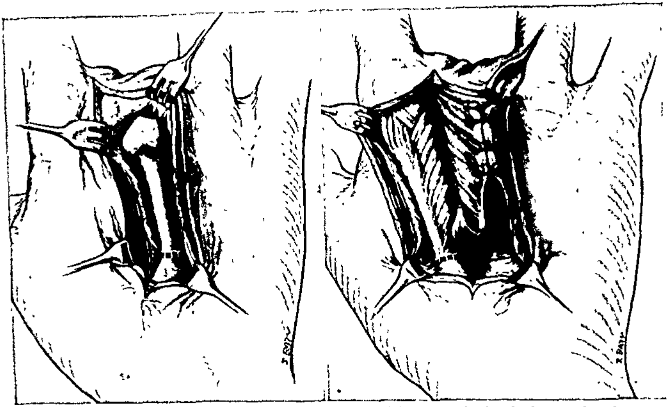

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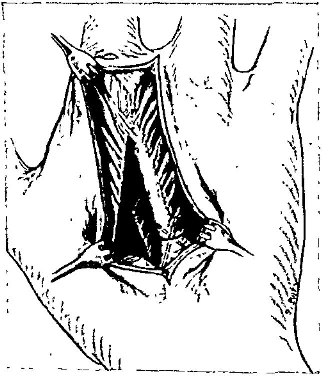

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DISCUSSION OF PROCEDURE

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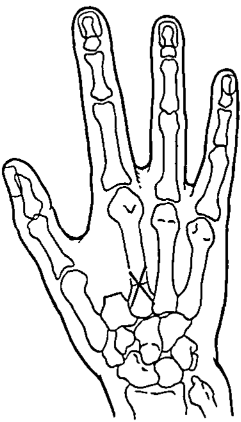

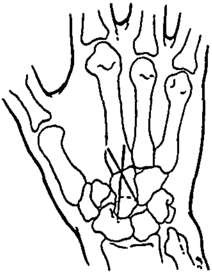

FIG. 6. Two methods of transposition give equally good results. If the second metacarpal is moved completely, it is secured to the capitate bone. When an osteotomy at the base of the second metacarpal is used, the bone can be fastened to the base of the excised third metacarpal.

FIG. 7. The only case of nonunion resulted when poor fixation at mid-shaft was attempted. The osteotomy should be carried out at the base of the metacarpal and the transposed bone fastened securely.

sider them here. In the author's cases stripping the muscle origin of the interosseous muscle has not disturbed the intrinsic function normally shown. The digits exhibit full flexion and extension with the usual adduction and abduction. No function of the adductor of the thumb is disturbed. Since the adductor arises in its transverse head from the shaft of the third metacarpal, one might suspect loss of power. This is not so. Since the third metacarpal is removed subperiosteally and the tube is closed, a firm band of scar tissue results. This band is anchored sufficiently to the adjacent metacarpal posts to give functional stability The web space between the thumb and index fingers will maintain its depth and normal contour following the ray transposition described. The question of holding the metacarpal heads together while bony union occurs in the third metcarpal arthrodesis arises frequently. The author has not encountered the need of a threaded Kirschner wire or any other form of fixation other than at the arthrodesis site at the base of the metacarpal. These arthrodesis wires can migrate and should be

checked by an occasional roentgenogram for position. The author does not remove the wires unless there is some indication to do so.

In transposing the index ray to the position of the third ray, it makes absolutely no difference whether the entire metacarpal is used or only an osteotomy at the base is completed (Fig. 6). The author used this different method on alternate patients in twenty such cases, and there has been no difference in end-results. When the entire index metacarpal is transposed, it is necessary to arthrodese the shaft to the capitate carpal bone. Technically, it is more difficult to divide completely the articular capsule between the index metacarpal and the lesser multangular carpal bone. No loss of power occurs from shifting the insertions of the extensor carpi radialis brevis and longus. Since this is done subperiosteally, these tendons still are fastened to the carpometacarpal articulation by firm scar tissue and have the same mechanical power. At present, the author favors the osteotomy at the base of the metacarpal because of the greater ease in performing the surgery.

Complications

When an unfamiliar procedure is carried out, there are bound to be complications. It is amazing to the author that more problems did not arise. The osteotomy is carried out best at the base of the metacarpal. The osteotomy should be a clean cut and not beveled or fragmented. At this level, the bone is quite cancellous and should lead to early solid union. The bone should be fastened by Kirschner wires so that they are held firmly in place. Figure 7 shows a case in which the arthrodesis was attempted in the shaft and was poorly fixed by a single transfixion wire. The resulting nonunion and angulation could be expected. This is the only case in the forty-three under discussion in which union did not occur.

A frequent complication of finger fractures is found in transposing an index ray. In function, the tips of the second, the third, the fourth and the fifth digits point to the volar prominence of the navicular or hook of the trapezium in flexion. This direction must be considered when securing the transposed metacarpal. In Figure 8 the deformity resulting from a deviated rotation is apparent. This can be corrected easily at a later date by a second osteotomy. To our knowledge this has occurred on only one occasion. In general, few complications have arisen.

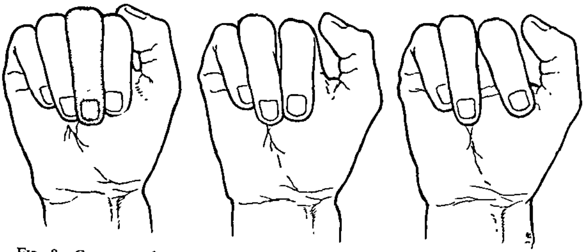

FIG. 8. Care must be taken to obtain proper position without rotation: (*left*) all tips of the finger point to the navicular in flexion; (*center*) proper transposition preserves the alignment, (*right*) poor positioning causes the finger to project from the grasp

SUMMARY

In the functional activities of the hand, *amputation of the third digit proximal to* the distal quarter of the proximal phalanx *results in marked disability*. When such an operation is necessary, consideration should be given to replacing the shortened middle finger by the index finger. Such a procedure will decrease the functional disability and produce a more balanced hand, with definite improvement in appearance. The operative steps for this surgical technic have been outlined. Two known complications resulting from the operation are discussed. The operation has been performed on 26 patients by the author and on 17 others by colleagues. All patients were engaged in occupations that required heavy use of the hand.

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Transposition del Indice, como Reimplaciamento del Medio

Summario in Interlingua

Le medio, i. e., le tertie radio, es importante in le function del mano como axe principal e como partenario del pollice in pincear. Amputation de plus que duo phalanges del medio resulta in un definite deformitate in le function del mano. Le remanente trunco del tertie digito protrude ab le mano in omne effortio de sasir. Le spatio inter le indice e le anulario permitte a micre objectos a glissar ab le mano

In 43 *patientes le residuo del tertie digito* esseva eliminate, e le secunde digito, i. e. le indice, esseva transponite pro clauder le lacuna. Iste operation esseva effectuate in patientes qui usa lor manos in labores pesante. Le patientes de omne le casos hic presentate esseva tenite sub observation durante plus que un anno.

Le intervention chirurgic comencia con un incision al aspecto dorsal del mano. Illo es placiate longitudinalmente supra le spatio inter le secunde e le tertie diaphyse metacarpal. Le periosteo del tertie osso metacarpal es aperite, e le osso es excidite per osteotomia a su base. Le diaphyse del secunde osso metacarpal es alora distachate ab le origine del prime musculo interosseodorsal. Le osso es dividite a su base. A iste tempore le tubo periostee del tertie osso metacarpal pote esser claudite. Le diaphyse del secunde osso metacarpal es portate in approximation con le base del tertie osso metacarpal e fixate illac con filo de Kirschner. Un bandage a gypso es mantenite durante sex septimanas pro obtener le union *del ossos*.

Le resultatos del operation ha essite multo satisfacente. Complicationes ha occurrite in duo casos In un de istos, le sito del osteotomia non esseva al base sed al centro del tertie osso metacarpal. Le transponite secunde osso metacarpal esseva mal attachate per medio de un sol filo de Kirschner. Le resultato esseva pseudoarthrosis. In le altere complication il se tractava de un imperfecte alineamento rotational del digito transponite, con le resultato que illo non participava in le action del sasir. Omne le altere patientes ha obtenite immediatemente resultatos multo satisfacente.

6

Amputations of the Fingers and the Hand

DONALD B. SLOCUM, M.D.*

FUNCTIONAL CONSIDERATIONS

It has been a common misconception that amputations through the fingers or the hand are a matter of simple detruncation of hopelessly affected segments with preservation of such tissues as can be covered satisfactorily by regional or transplanted integument. Such a point of view is scarcely consistent with the functional concepts of the present-day surgeon: that total treatment embodies not only maximal preservation of serviceable remnants but also planned reconstruction to maximal function. The latter should be initiated at the time of original surgery, whether this is of an elective or an emergency nature. It is the purpose here to present some of those principles that will aid in planning the best use of the remaining segments in the amputated hand.

The author has emphasized repeatedly the value of the three basic functions of the hand: grasp, pinch and hook. Grasp embraces the action of holding an object against the palm by the opposed thumb above and the fingers below. Pinch consists of apposing the tip of the thumb to the tip of one or more fingers. This may take several forms: (1) fingernail pinch, as in picking up a coin; (2) pinch with the pad of the thumb against the pad of the index finger, as in picking up a piece of paper; (3) lateral pinch, in which the pad of the thumb holds an object against the side of the index finger, as in holding a teacup or a book; (4) chuck-action pinch, in which the pad of the thumb holds an object against the pad of the index finger and the side of the distal phalanx of the middle finger in much the same way as a 3-pronged machine chuck (this may be seen in such common activities as holding a pencil); and (5) multiple pinch, in which the pad of the thumb apposes the pads of all fingers. This last may be demonstrated by picking up multiple small objects, such as shot or beans. Hook action is simply what the name implies; it utilizes the fingers alone and is seen in such actions as lifting a suitcase or the edge of a table.

Since it is the objective of amputation surgery to preserve and restore function, three basic considerations must be evaluated before operation may be considered:

1. The function or the functions that the injured digits fulfill.

2. The extent to which the loss of each amputated segment affects the hand.

3. The relative importance of each basic hand function to the individual as regards appearance, occupation and general use of the hand. Since these three factors often necessitate variation from standardized procedure, it is only through a knowledge of them and an assessment of their relative importance that the level and the method of amputation may be chosen most judiciously with a view to restoring maximum function.

The number of digits and metacarpals, their length, strength, sensation, mobility, and motivating power, are the fundamental factors to be considered. The contribution of each of these elements to the remaining hand must be weighed carefully in view of

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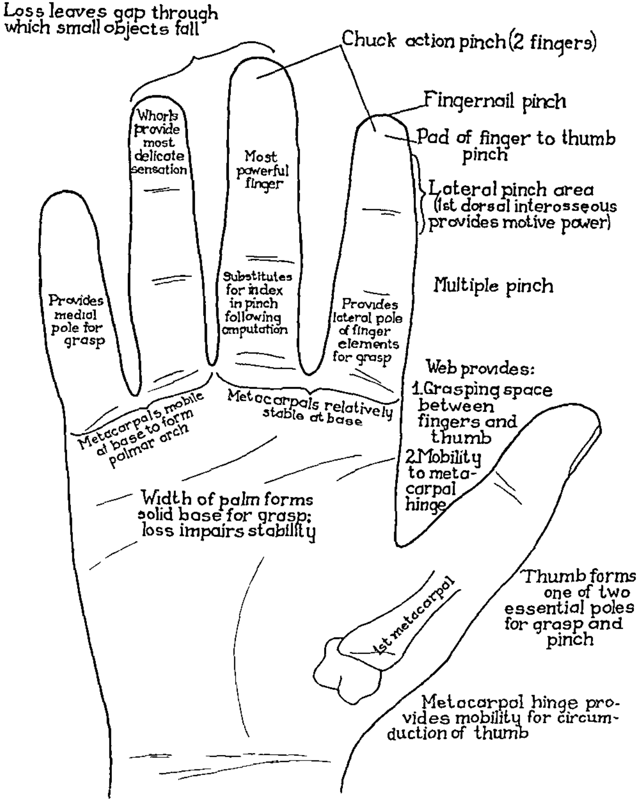


FIG. 1. Functional considerations in hand amputations.

both the surgery at hand and the future reconstructive procedures that may be carried out To this end, each finger and its metacarpal will be considered individually in regard to those points of surgical interest encountered commonly in amputation.

The thumb is the most important single digit of the hand. Its purpose is to serve the hand in grasp and pinch, and its loss results in quite a useless hand, in which only minor substitutionary movements remain. The effectiveness of the thumb is dependent

to a large measure on its length and mobility. Its wide range of circumduction is dependent on a proper balance of motor elements, the integrity of the first metacarpal hinge, and the freedom of movement permitted by the skin and the muscles lying in the web space between the thumb and the index finger. While the free range of motion between the first metacarpal and the greater multangular bones—the metacarpal hinge—may seem to be out of place in a discussion of amputation, its import will soon be realized in the light of such procedures as finger transplant, bone- and tube-graft substitution of the totally amputated thumb, and apposition to the ulnarly placed digits when the index and the middle fingers have been lost. Of no less import is the web space, for not only does it provide the freedom of action required by the thumb but its depth supplies the cleft in which an object falls in grasp. When the thumb is shortened, this cleft may be so shallow as to require plastic procedures involving skin and muscle to deepen it to the point of effectiveness. The thumbnail, paired with that of the index finger, is essential to fingernail pinch. The skin of the pad of the thumb forms the principal tactile and pressure area, while that on the outer side of the distal phalanx ranks second in importance. Needless to say, plastic reconstruction of the thumb following amputation is carried out in such a manner as to minimize scar and avoid anesthetic areas.

The index finger ranks next in importance to the thumb, since it provides the lateral pole of the finger elements in grasp and most frequently apposes the thumb in pinch. In normal grasp it gives the finger elements stabilizing breadth as grip is consummated; in wide grasp, as in throwing a football, the radial deviation of the index finger effected at the metacarpophalangeal joint by the first dorsal interosseous muscle provides the necessary span. For fingernail pinch the preservation of the nail is essential. In apposing the pad of the index finger to the thumb or in chuck-action pinch, a painless scarfree tactile pad must remain. For lateral pinch, sound integument must be provided over the area on the radial side of the distal half of the middle phalanx and the proximal half of the distal phalanx. Length is extremely important in the index finger, for with each fractional loss in length of the index finger its function decreases. As this loss approaches the distal interphalangeal joint, pinch is transferred to the middle finger. As the proximal interphalangeal joint is reached, grasp is largely lost except as the remaining stump contributes to the breadth of the palm. In the latter instance, not only is the remaining stump awkward but often it is bumped and bruised. The cosmetic effect is one of unsightliness. At levels above the metacarpal neck, the stabilizing effect of the transverse metacarpal ligament is lost and the bony prominence of the shaft interferes with grasp as it bulges into the web space, which otherwise would pass in a smoothly flowing curve between thumb and middle finger.

The middle, or long, finger fills the span in grasp and prevents small objects from falling through the fingers of the clenched hand. Because of its strength, it acts in conjunction with the index finger to provide strength and stability to grasp. It reinforces the index finger in lateral pinch so that heavier objects, such as books, may be carried between the side of the index finger and the thumb. Since it is the strongest of the fingers, it is used most commonly in hook action, where only a single finger is required. When the index finger is amputated, the middle finger substitutes for it in apposition with the thumb in pinch. With amputation of this strong middle finger the following functions are lost: the ability to hold small objects in the clenched hand, the reinforcement of the index finger in lateral pinch, the participation in chuck action and multiple pinch, and strength of grip. Amputation through the third metacarpal bone brings on even more serious disability. With the loss of the stabilizing effect of the transverse metacarpal ligament, the adjacent fingers tend to rotate away from the amputated ray. In its function as the pivotal pillar of the palmar

arch, about which the fourth and the fifth fingers, tethered by their transverse metacarpal ligaments, swing palmarward toward the thumb, the middle finger acts as a center of rotation for those many dexterous movements that involve the change in the palm of the hand from the flat to the cupped position. In addition, the third metacarpal acts as the point of insertion of the adductor pollicis muscle, which serves to consummate the force of grasp and pinch. Little imagination is required to see the impairment of strength and mobility arising from the loss of the key metacarpal.

The ring finger serves chiefly to fill in the span and, in concert with the little finger, provides the palmar arch with mobility. Its loss impairs these two functions as well as decreasing the contribution of the digit to grasp, hook and multiple-pinch actions. Metacarpal loss results in rotatory deviation of adjacent fingers. The little finger is chiefly important because of its ulnar position, where it lends breadth and stability to grasp when the span is wide. It also provides the palmar arch with mobile dexterity. The metacarpal furnishes a good share of the stability afforded by the breadth of the palm in grasp.

In summation, a knowledge of the function of each individual component of the hand is a fundamental requirement in creating an operative plan for either primary or delayed reconstruction of the amputated fingers and hand. Some of the more common considerations have been presented.

SINGLE-FINGER AMPUTATION

Amputation through a single digit is the most common form of loss in the hand. Too often, repair directed toward skin closure alone is the sole objective, with little thought of comfort, appearance and future use. The thoughtful surgeon will develop the operative plan to encompass those points in technic that will provide the best functional and cosmetic results. To do this, he will consider each tissue individually as to the necessity for its removal, substitution or preservation Only then will he be able to apply the specific method that best suits the individual situation. In the following pages the general principles of tissue care, with regard to their functional qualities, will be considered and later related to certain standard procedures which, in most instances, may be applied with only a little variation.

General Considerations

The length of a finger following amputation is of utmost importance. Up to the level of the proximal interphalangeal joint, loss of function is in direct proportion to loss of length. The bone should not be shortened if any alternative exists; usually it is preferable to cover a terminal wound with skin of quality less desirable than the normal integument through use of atypical skin flaps, plastic rearrangement of the skin or skin-grafting than to sacrifice needed length. Amputation through the proximal phalanx leaves a stump that, within itself, is virtually useless. However, it does contribute to the breadth of grasp in the index and the little fingers, and aids in preventing small objects from falling between the fingers during grasp in the ring- and the middle-finger positions The metacarpal bones supply the breadth of palm so essential to stability in grasp. This function is preserved if the metacarpal heads remain, but, if the finger is removed above the level of the transverse metacarpal ligament, metacarpal stability is lost. This results in a mobile bony prominence in the web space when the index metacarpal is amputated through the shaft. Similarly, when amputated in its distal one half, the fifth metacarpal is mobile and often painful. In amputations through the metacarpal shafts of the middle or the ring finger, not only is the hand narrowed but rotary disturbances of adjacent fingers occur.

The skin cover of the amputation stump should be freely movable and nonadherent to the underlying bone, should have good subcutaneous padding and normal sensation, and should be tough enough to withstand the

trauma of daily use. Since palmar skin best fulfills these requirements, it is used whenever possible. Scar should be linear and nonadherent, and it should lie away from pressure areas wherever practical. For these reasons, long palmar and short dorsal flaps are preferred when they are applicable. The skin never should be drawn tightly over the bone, for this will cause restriction of motion of the stump, spreading of the scar with adhesion to the bone, and pain and restrictive tension at the finger's end.

The power and the mobility of the stump may be retained best by avoiding scrupulously any violation of joint integrity or soft-tissue contracture. The most common sources of such contracture lie within the skin or result from the checkrein action of adherent tendons. The strength of the various parts of the hand is dependent on muscle power. In finger amputation, usually this is not affected in the normal course of events, for each phalanx has a separate and an independent motivation: the distal phalanx by the extensor expansion and the flexor profundus; the middle phalanx by the extensor expansion and the flexor sublimus; and the proximal phalanx by the common extensor tendon and the lumbricales. While at first glance it would seem to be logical to sew the tendons to the end of the stump to reinforce its power, this practice must be avoided, for not only does it lead to restricted motion within the stump itself but it affects the movement of adjacent fingers. This latter effect is based on the anatomic fact that the long flexors and extensors of the fingers interdigitate at higher levels so that they can effect motion independent of one another only in the mid ranges of contractile excursion. To demonstrate this, the reader should first make a fist and note how the fingers close tightly into the hand Next, with the hand in the neutral functional position, he should hold the ring finger in full extension at all joints and attempt full closure of the hand. In these circumstances he will find that the profundus tendons are inactivated completely and that the range of sublimus contraction has been reduced materially. Similarly, he may now hold the ring finger in full flexion and check the loss of extension of the other fingers. When amputation occurs at the level of the metacarpal heads, a different situation applies, for here no motive power remains to provide the excursion for the remaining ray. This assumes least importance in the index- and the middle-finger metacarpals, which are relatively fixed at their carpometacarpal joints, but in the ring- and the little-finger metacarpals motive power must be provided to ensure the strength and the mobility of the palmar arch, which carries the palm from the flat to the cupped position and adds much to the appearance of the hand in movement. Again, it is well to add a word of caution: do not suture the tendons to the metacarpal head under strong tension, for here again the freedom of movement of the other fingers may be affected. Allowance for the excursion of the fingers prior to metacarpal motion (which for the most part takes place at the extremes of finger movement) must be made. In fresh amputations this may be accomplished best by suturing the extensors and one long flexor (preferably the profundus) to the end of the stump at their so-called rest length. The rest length of muscle is that point to which a muscle will contract spontaneously when freed from its insertions while unaffected by nerve stimulus. It represents an approximate mid-point in the total excursion range of a muscle where the effect of the elastic elements has been spent but the effectiveness of the contractile elements is at, or near, its maximum. When late reconstruction is carried out in cases in which the tendons have been allowed to retract, they should be sewn with the tendons drawn downward under moderate tension, for here myostatic contracture has taken place in the muscle-tendon system and the point of muscle rest length has been shifted to a position shorter than the rest length the normal active muscle.

The digital nerves need no special treat-

ment other than to ensure that a minimal terminal neuroma forms and that the nerve is mobile and not fixed in scar tissue. To this end, the nerve is sectioned clearly under normal tension at a point ¼ inch or so above the bone end so that it will lie in a normal bed of soft tissue free of scar. It is never drawn down, sectioned under strong tension and then allowed to retract upward, for this practice may lead to intraneural tears with subsequent scarrring and form the base for later pain and disability. Alcohol and other sclerosing solutions are both unnecessary and undesirable. Ligature is not required, since intraneural bleeding is scant.

Bone is severed at the most distal level, which permits easy approximation of the skin and subcutaneous tissues over its distal end. Care should be taken *not* to divide it by a single bite of bone-cutting forceps or rongeur, for the crushing effect on hard cortical bone might result in longitudinal fracture that would either increase the local scar or extend upward to the adjacent joint. It is better to divide the bone with a small saw or to rongeur away one cortex at a time until complete section is achieved.

Fingertip Amputations

Amputations of the fingertips are a frequent sequel of injury and usually result from slicing, crushing or avulsing wounds. Often, disability is out of all proportion to the extent of the wound if the treatment is improper or inadequate. If the wound is allowed to heal by granulation and scarring, its healing will be delayed and the stump may remain tender and painful. Eventually, such a wound will become covered by an anesthetic, tender scar that frequently is subject to breakdown under minimal trauma, and, should this occur, revision of the stump will be required with attendant loss of length. Ideally, the wound should be clothed by adequate well-padded skin and be relatively free of scar, and it should have a good cosmetic appearance. Since direct pressure is seldom borne upon the tips of the fingers, normal sensation, although desirable, is not imperative; therefore, skin grafts are permissible. The importance of padding by subcutaneous tissue should be stressed, for its absence will result in adhesions to the underlying bone that are painful on pressure and at the extremes of motion. Since adequate skin coverage should be obtained as soon as possible to avoid the painful cicatrix that follows in the wake of a granulating wound, the only justification for open amputation is in a situation where infection exists or is imminent because the safe period for primary closure has passed. In such instance, the wound should be cleaned up as rapidly as possible by débridement, moist dressings, etc., and skin coverage should be obtained at the earliest possible time consistent with sound surgical judgment.

The objectives in the repair of fingertip amputations are to provide skin coverage with sufficient subcutaneous padding, to maintain maximum length, to obtain maximum function in the shortest possible time and to provide skin with sensation if the location of the wound is such that the tactile area has been denuded.

The choice of treatment depends on the location of the wound and the extent of tissue loss for skin and bone, or skin, bone and fingernail may be involved. The simplest solution is reamputation at a higher level. This provides excellent skin coverage, but, due to the fact that the dorsal skin cannot be mobilized because of the presence of the fingernail, it results usually in a loss of valuable length and, therefore, should be avoided when an alternative method exists. When the nail-bed skin remains distal to the moon of the fingernail, it may be utilized for closure as though it were skin. Free split-thickness skin grafts provide excellent coverage when applied to sound base of subcutaneous tissue. They are particularly desirable on the dorsal aspect of the finger, where trauma is less likely. When the nail bed is involved distal to the germinal layer in split-thickness skin graft, frequently it will

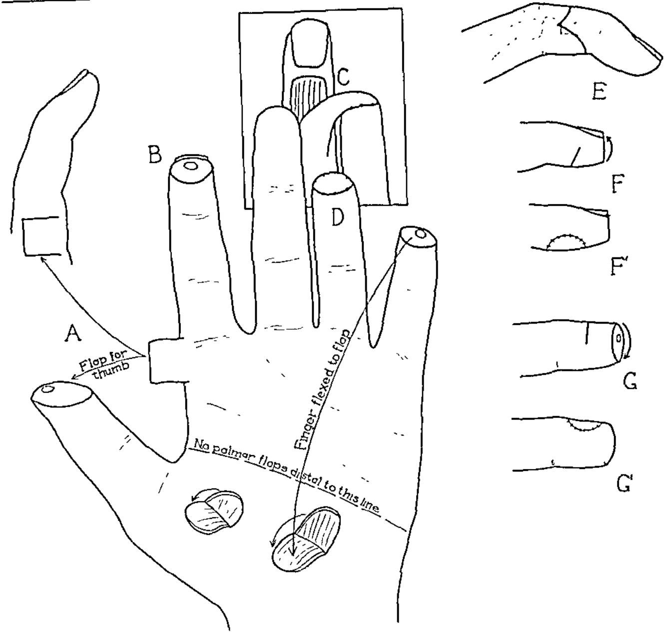


FIG. 2. Amputations through the fingers. (A) Flap graft from side of index finger to the tip of the thumb. (B) Index fingertip amputation preparatory for flap from thenar eminence. (C) Flap from dorsum of finger to adjacent amputation stump. (D) Free split-thickness or full-thickness skin grafts for terminal wound coverage. (E) Incisions for elective finger amputation. (F & F') Palmar sliding flap for fingertip amputation. (G & G') Dorsal sliding flap for coverage of a terminal wound above the level of the nail. Note split-thickness skin graft covering donor area. (Modified from Slocum, D. B.: Amputations *in* Campbell's Operative Orthopaedics, St Louis, Mosby)

substitute well for the distal nail bed In these circumstances, it may even be applied directly to bleeding bone, for it will be protected by the outgrowing nail. The free full-thickness skin graft will maintain length better and provide more durable skin than the split-thickness graft. It will serve more efficiently in areas where pressure may occur, such as the anterior aspect of the fingertip or, in the case of the index finger, the lateral side of the tip. Like the split-thickness graft, it requires a good bed of subcutaneous tissue if adhesions to the underlying bones are to be avoided. When bone is exposed, it should be covered with local subcutaneous tissue, if available, or it should be removed to a point at which this can be accomplished before a free skin graft is

applied. The donor area may be selected from any available site, but preferably from an area where subcutaneous fat is minimal and the skin normally is pliable. In most instances the flexor surface of the forearm is used, except in women, where it is avoided for cosmetic reasons. The groin and the lateral aspect of the thorax also provide alternative sources for skin. Following excision of the full-thickness free skin graft, usually the wound created by its removal is closed by a diamond-shaped plastic closure.

When the bone is denuded or the loss of subcutaneous tissue is excessive, skin flaps often are used. They provide an excellent covering for the fingertip, but technically the operation is slower and more difficult than when free grafts are used, and immobilization of the hand to the donor area is awkward and restricting.

The local flap grafts may be of the sliding or the cross-finger type. There are several varieties of sliding graft. These find their greatest use in transverse amputations, and they have the advantage of immobilizing only the injured finger. In the anterior aspect of the finger, the sliding graft described by Woughter is excellent. An incision is made transversely at a distance above the wound roughly equivalent to the denuded transverse diameter of the amputated finger and extends from the mid-medial to the mid-lateral aspect of the finger The skin and the subcutaneous tissue are undermined and the flap is rotated distalward as one would rotate the visor on a coat of armor. The graft is sutured in position, and the defect left is covered by a split-thickness skin graft. Another method has been described by Kutler. This involves the principle of utilizing a V-shaped incision of skin and subcutaneous tissue on either side of the finger, leaving the circulation intact. The apex of the "V" points proximalward. The two triangular flaps that have been created now are shifted downward to cover the end of the stump, where they are sutured in the mid-line. The upper end of the defect is closed by side-to-side suture until the point of the distally migrated graft is again reached, where the skin is sutured to the sides of the graft. A third method consists of making a mid-lateral incision that swings proximalward a sufficient distance to create a mobile graft which then may be undermined and swung over the end of the bone to the opposite side of the finger. Usually this can be closed directly, but occasionally split-thickness graft may be required to aid in coverage of the defect created by the transplantation of the skin.

The cross-finger graft is a valuable method of covering the defect of an adjacent finger. A U-shaped incision is made on the dorsum or the side of the adjacent finger, and the flap that always has its base proximally is lifted and then rotated to cover the adjacent fingertip and sutured in position. The defect and the base of the flap are covered by a free skin graft to avoid an open wound. While this type of graft is excellent for most fingers and is applicable for coverage of the thumb when the middle, the ring or the little finger is used as the donor site, it is not wise to take the cross graft for the thumb from the index finger, for almost invariably the transplant of the skin from the lateral side of the digit would impair its future lateral pinch. A better source for coverage for the thumb is to utilize the skin of the index finger overlying the lateral aspect of the proximal one half of the proximal phalanx where pressure seldom falls. A U-shaped flap is formed with its base anteriorly. Then it is lifted from the dorsum and swung anteriorly to a point at which it can cover the thumb defect. A split-thickness skin graft is used to cover the base of the skin flap and the raw surface left by its elevation.

Regional flaps frequently have been obtained from the thenar eminence and the base of the palm. While easily created, these grafts have lost in popularity because of the scarring that often results in the palm of the hand. If they are used, care is taken to place

the donor site proximal to a line drawn between the ulnar aspect of the metacarpophalangeal joint of the thumb and the base of the fifth metacarpal, for almost invariably flaps taken distal to this point will result in painful scarring. To create such a flap, the location is determined by flexing the finger to the base of the palm and locating the point at which it rests most easily. A U-shaped flap is turned up from the hypothenar eminence with the base of the flap placed in the most convenient position for coverage. Of course, the defect is covered with a split-thickness skin graft.

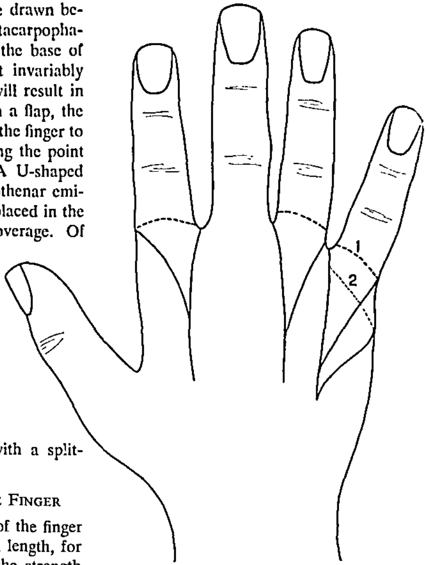


FIG. 3. Incisions for metacarpal amputation.

AMPUTATIONS THROUGH THE FINGER

The objective of amputation of the finger is to preserve all possible useful length, for it should be remembered that the strength of the hand is lessened by the loss of each digit and each fraction of length within a digit; therefore, severance should be carried out at the most distal level compatible with sound integument. The only exceptions are those cases in which protruding stump is contraindicated by cosmetic demand or by its awkwardness relative to the demands or the occupation of the patient.

The classic description of skin flaps used in amputation of the finger is to create a long palmar and a short dorsal skin flap in the ratio of two to one. The palmar flap is made tongue shaped rather than semicircular to avoid "dog-ears" at the margins of the suture line. Unfortunately, however, when the amputation is being performed as a result of trauma, typical skin flaps seldom can be created. When the situation demands maintenance of length, and circulation is adequate, atypical flaps and minor plastic procedures are used. Supplementary free skin grafts may be used in areas not subjected to heavy pressure. Since the skin overlying the fingers is relatively fixed, usually more length is required than might be anticipated. Skin never should be sewn under strong tension, since this inevitably will result in tightness over the end of the stump, a broad, tender scar at the suture line and/or occasionally tissue breakdown. To ensure adequate skin length, usually the dorsal flap is cut with the finger in flexion and the palmar flap with the finger in extension. Although at the time of closure the flaps may appear to be quite loose, the elastic tension within the skin soon will draw them up snugly over the stump ends. "Dog-ears" at the end of the

suture line generally take care of themselves through contraction of the skin. However, if they seem to be too redundant at the time of closure of the wound, a small V-plasty incision may be made at each side of the intended suture line. Should they remain after healing of the wound, they may be excised by an elliptical incision. The "dog-ears" should always be allowed to remain when an atypical flap is used that swings over the end of the stump to the opposite side; here the removal of a wedge of skin from either side of a long flap may reduce its width as much as 50 per cent and endanger the circulation. The bone is severed at a level that allows easy approximation of the skin. As has been noted, it never should be severed by a single bite of bone-cutting forceps or rongeur, since the crushing effect may cause longitudinal fracture that will result in increased local scar or, in some instances, extend upward into the joint. The nerves are located and freed upward in their beds to the point of intended section in normal, healthy soft tissue. Usually the bed of the nerve is spread with a hemostat to the point of intended section, and the nerve there is severed with a sharp knife or scissors. There should be no injection of sclerosing substances and no use of ligatures. The tendons are severed by simple transverse section and allowed to retract. They never are sewn over the end of the bone because of the danger of contracture. Blood vessels are ligated with 3-0 catgut when necessary, and closure is carried out with interrupted skin sutures.

When simple closure with available skin cannot be effected and length still maintained, alternative plastic procedures may be used Free skin grafts, either of the full-thickness or the split-thickness type, form excellent coverage for dorsal, terminal and lateral wounds in the freshly amputated finger They should be applied early so that the inevitable infection associated with an open wound does not occur and form the basis for cicatrix Sliding-flap closure may also be used. It forms the same visorlike flap described for fingertip amputation except that the skin is taken from the dorsum of the finger to avoid palmar scar. Therefore, it is practical only above the fingernail level. It is used when section of the finger is essentially in a transverse plane. The sliding-flap method, utilizing a lateral incision that extends upward, then turns transversely over the dorsum of the finger, is also of value. Here, again, the tissues are undermined and the flap is freed at the level of subcutaneous tissues and swung distalward to the opposite side of the finger to cover the exposed end of the amputated digit. An auxiliary split-thickness skin graft may be required for closure.

Amputations Through the Index Finger and the Second Metacarpal

The index finger is next in importance to the thumb. Because of its position, it is the primary finger used in pinch and one of the *two polar finger elements in grasp.* Because of its stability at the carpometacarpal joint and the nearly direct pull of the flexor tendons, it is one of the strongest digits. Loss of function is in direct proportion to its loss of length. When amputation is carried out distal to the proximal interphalangeal joint, the principles of finger amputation are applied and all possible length should be saved, care should be taken to preserve the skin on the lateral aspects of the finger because of its function in lateral pinch. Above the proximal interphalangeal joint, the stump is too short to be useful in pinch (its role in this function being taken over by the middle finger), and the surgical plan is based on the occupational and the functional demands of the patient and the need for cosmesis.

When amputation occurs between the level of the metacarpal head and the proximal interphalangeal joint, the stump provides the palm and the hand with breadth and stability in grasp. However, the finger element is *useless for pinch, it provides little flexor* power for grasp, it often lags behind the other fingers as they are flexed into the posi-

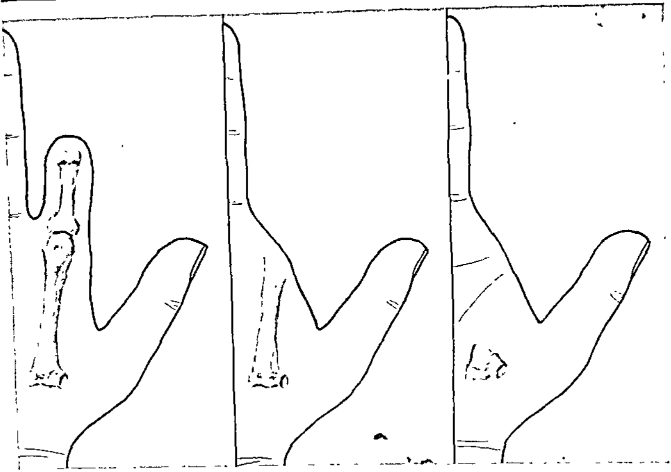


FIG. 4. Amputations through the index finger. (*Left*) Amputation stumps proximal to the interphalangeal joint are poor cosmetically, and they provide little function other than adding breadth to the hand. (*Center*) Metacarpal shaft amputations impede the web space and provide little stability, and often they are painful in grasp. (*Right*) Amputations through the base of the metacarpal or disarticulation at the carpometacarpal joint clear the web of projecting bone and add dexterity. Also, they are good cosmetically. However, they narrow the width of the palm.

tion of grip, and it projects in such a manner as to make the hand awkward and unsightly. Because of this awkwardness it is subject frequently to bruising. Such a hand with the short index stump is primarily a laborer's hand, and, for practical reasons, the stump should have a covering of palmar skin and its scar should fall on the dorsal aspect.

Amputation through the metacarpal shaft is undesirable. The shaft no longer provides a stable base for grasp because of the loss of the transverse metacarpal ligament, and the end of the amputated metacarpal projects into the web space between the index finger and the thumb, where it not only forms an unsightly bulge but becomes a hindrance, and often a painful one, during grasp and grip. Even in the presence of acute trauma, this bone level should not be permitted to remain, since most assuredly it will cause trouble at a later date and require secondary operation. It takes only a few moments to sever the bone at the more desirable level—at the metacarpal base.

Amputation through the metacarpal base or disarticulation at the level of the metacarpal joint provides a broad, mobile web space free of bony impediment. It is indicated in amputations above the proximal interphalangeal joint, where dexterity and cosmesis are the primary considerations. The incision should follow along the ulnar side of the second metacarpal on its dorsal aspect so that the scar will fall well away from the

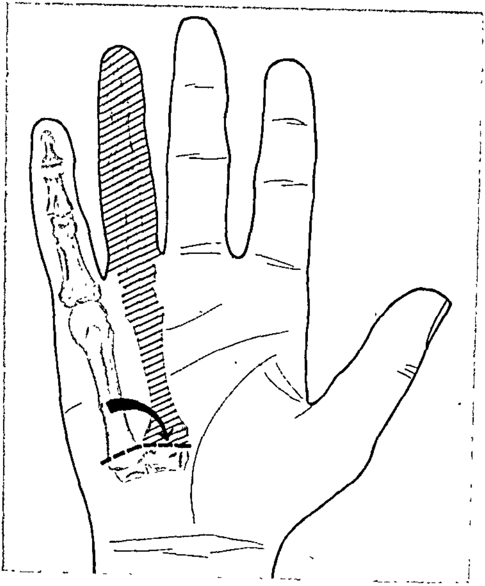


FIG. 5. Amputation through the shaft of the third or the fourth metacarpal permits rotary deformities of adjacent fingers. It is corrected best by finger transplant: in the case of the ring finger, the little finger is moved to the base of the fourth metacarpal; in the case of the middle finger, the index finger is moved to the base of the third metacarpal (Modified from Bunnell, S: Artificial Limbs 3: 76)

web space. Whenever it is practical to do so, the first dorsal interosseous muscle of the index finger is transplanted to the middle finger to ensure strong radial deviation. If this cannot be done, the middle finger often lacks the strength necessary for lateral pinch, even though it is bolstered by the ring and the little fingers beside it, and a tendon graft may become necessary to reinforce this action.

Since amputation through the metacarpal often involves accompanying trauma to the web space, it is probably well to mention here that the skin never should be borrowed from this area to effect closure of the wound. If the web space is impaired by scar or its skin is shortened, it may have a tethering effect on the thumb and prevent its normal wide range of circumduction. A transverse scar overlying the web space never should be permitted to remain, since most assuredly it will contract, drawing the thumb toward the index finger; it is better either to interrupt the suture line in a zigzag fashion or to supply supplemental skin.

Amputation of the Third and the Fourth Metacarpals

Disability from amputation through either the third or the fourth metacarpal arises from the tendency for small objects to fall through the space left by the missing fingers in the cupped or grasping hand and deviation of the adjacent fingers during flexion. The architecture of the hand is such that each metacarpal head, with the exception of the

first is bolstered by its neighbors and fixed by the transverse metacarpal ligaments. When the third or the fourth metacarpal bones are amputated below the level of the metacarpal head, the integrity of these ligaments is lost, the adjacent metacarpals become unstable, and rotary deformities of the fingers occur.

When the third or the fourth metacarpal is amputated, a racquet incision is used. A longitudinal incision is made along the dorsum of the metacarpal to the level of the metacarpal head. From this point it swings to the side of the finger at the web space and crosses the anterior aspect of the finger at the level of the proximal flexor crease, whence it follows dorsally and proximally to join the longitudinal incision. Wound closure is carried out in accordance with the standard principles so that the scar falls on the dorsal aspect of the hand. The tendency toward rotary deformity of the fingers should be corrected as soon as the condition of the tissues permits. Judgment frequently will indicate that stabilization should not be attempted when deep and extensive tissue trauma has occurred. Then it is better to await the return of the tissues to a healthy state before reconstruction is attempted.

When reconstruction is practical, three elective procedures may be considered. The simplest method, though often not the most satisfactory, is complete excision of the involved metacarpal with collapse of the two adjacent metacarpal heads in such a manner that a scar-tissue bridge will substitute for the transverse metacarpal ligaments and afford some stability. Unfortunately, this procedure provides only a fair rotary stabilization, and usually some finger deviation remains; also, there is loss of width and the hand often feels tight and restricted. A second alternative is the transplant of the little finger to the position of the amputated ring finger or of the index finger to a position of the amputated middle-finger metacarpal. When this procedure is undertaken, osteotomy should be done at the base of the metacarpals sufficiently away from the joint to ensure its integrity. This yields excellent rotary stabilization and gives a good cosmetic result, but it weakens the grasp because of loss of breadth in the palm. Wherever tissues permit and cosmesis is not a prime consideration, replacement of the amputated metacarpal by a bone graft from the fifth metatarsal of the foot provides good rotary stabilization and maintains the breadth of the palm. The length of the bone graft from the foot will depend on the length of the portion to be replaced. Internal fixation by any of the standard methods is desirable to ensure healing of the graft.

Amputation Through the Little Finger and the Fifth Metacarpal

Amputation through the fifth finger is carried out in the usual way described for finger amputations. A short finger stump, consisting of the proximal phalanx alone, often is awkward, useless and unsightly. Actually it is a hindrance in such actions as placing the hand in the pocket, where often it catches on entry. It is also subject to frequent bruising. In such an event, reamputation should be carried out at a high level. In laborers this should be done through disarticulation at the level of the metacarpophalangeal joint to afford the hand maximum breadth for grasp. When this level is selected, a bony prominence remains over the metacarpal head. This may be corrected by beveling the lateral and the posterior aspects of the metacarpal head, so that, when the skin is drawn over it, a smooth, rounded surface is presented. The profundus tendon should be sutured to the metacarpal head at the rest length of the tendon to ensure its mobility.

When the fifth metacarpal is to be removed, a dorsal racquet incision is used. The longitudinal limb of the incision is carried along the radial side of the fifth metacarpal and the distal end of the incision loops about the finger at the level of the proximal flexor crease. This ensures that

the incision will fall well away from the hypothenar eminence when the wound is closed.

Amputation through the distal one half of the fifth metacarpal shaft is not a satisfactory procedure because of the mobility of the remaining bone. The resultant stump often is painful and unsightly, and lacks muscular control. When the metacarpal is amputated in its proximal one half, the lateral aspect of the bone should be beveled to form a smooth and even contour beneath the skin. When this cannot be accomplished, the bone should be amputated at a higher level near the base. Either of these two bone levels gives an excellent cosmetic result, the loss of the finger being scarcely noticeable.

Amputations of the Thumb and the First Metacarpal

The thumb is the most important single digit in the hand. Its function is to serve the hand in grasp and pinch; its loss results in a relatively useless hand in which only hook action remains. Treatment depends on the level of amputation.

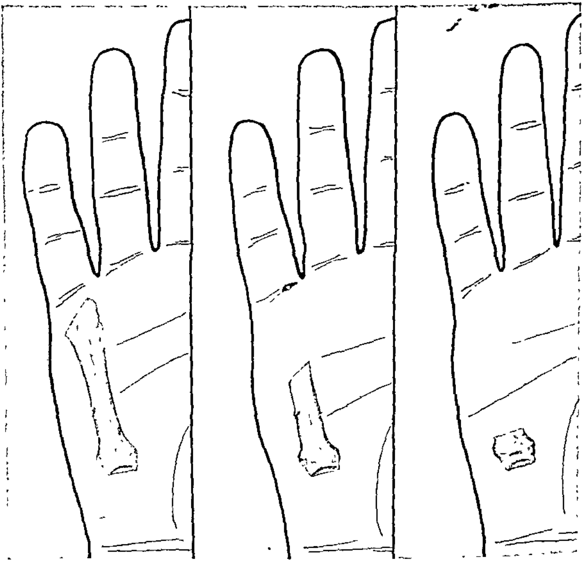


FIG. 6 Amputations through the fifth metacarpal (*Left*) In disarticulation at the metacarpophalangeal joint, the metacarpal head is beveled on its lateral and dorsal aspects to create a smooth, even contour. (*Center*) Amputation through the distal one half of the metacarpal is to be avoided because of increased mobility and the prominence of the bone beneath the skin; in the proximal one half, the side of the metacarpal is beveled to eliminate any bony projection. (*Right*) Amputation through the metacarpal base results in a smooth, even contour of the hypothenar region.

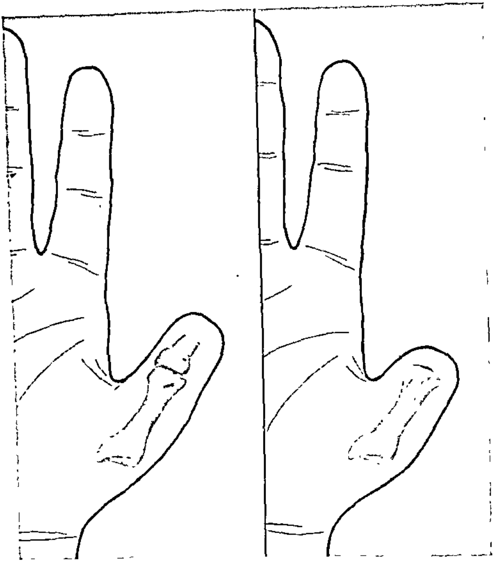


FIG. 7. Amputations through the thumb. (*Left*) Amputations of the proximal one half of the proximal phalanx require web deepening for more effective grasp. (*Right*) Amputations proximal to the metacarpal head require lengthening of the thumb or replacement of lost length by finger transplant or substitution.

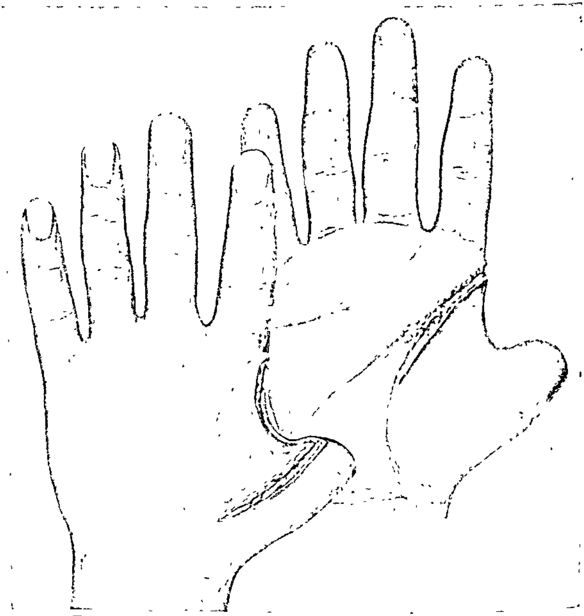
Amputation distal to the mid-shaft of the proximal phalanx is carried out under the same general principles that apply to finger and fingertip amputation. It should be stressed that the thumb is so important that no portion of it that would have functional utility following reconstruction should be removed. Therefore, at the time of the original injury, particular thought should be given to those reconstructive measures that will preserve ultimate maximum length.

Amputation between the mid-shaft of the proximal phalanx and the neck of the first metacarpal is performed in accordance with the principles of finger amputation. However, at this level an additional problem presents itself: to provide a web space between the thumb and the index finger of sufficient depth, width and mobility to allow the thumb to function in grasp and pinch. Additional depth of ¾ inch to 1 inch is provided by partial stripping the origins of the first dorsal interosseous and the insertion of the adductor pollicis tendon from the first metacarpal. The deepened web space must be covered by adequate mobile skin. When no scarring is present in the web space, this may be accomplished by Z-plasty, a jump flap or an advancement flap. As Z-plasty is probably the most acceptable procedure, it alone will be discussed in detail here.

The incision starts in the palm of the hand about the mid-point of the thenar crease, it follows the crease to the lateral aspect of the index finger, then it crosses the web space at the height of the skin fold to the posteromedial aspect of the thumb. Next, it swings proximally toward the index finger at an angle of approximately 60° to end midway between the first and the second metacarpals ½ to ¾ inch distal to their base. The flaps are lifted from their beds and the

palmar flap is swung posteriorly to wrap around the base of the thumb, while the dorsal flap wraps about the base of the index finger. The wound then is closed in such a manner that the suture line crossing the web space lies in the anteroposterior direction. Alternatively, free flap or pedicle skin grafts may be used according to the dictates of surgical judgment.

There are instances in which the very short thumb stump can be of practically no functional value unless the web space is widened. This can be accomplished by amputation of the index finger at its metacarpal base. However, the index finger should be sacrificed only when it has been damaged to the point of uselessness or must of necessity be amputated proximal to the proximal interphalangeal joint, or when, because of extreme loss on the radial side of the hand, the value of the web cleft outweighs the value of the index finger or stump. When this procedure is carried out, the middle finger substitutes for the index finger in pinch, an action that is enhanced by the transplant of the first dorsal interosseous to the middle finger. There may also be instances in which angulated fractures of the thumb or impair-



FIGS. 8 to 10. Z-plasty for deepening the web space. FIG. 8. Incision.

ment of the first metacarpal-greater multangular joint will prevent mobile apposition of the thumb to the fingers. Here osteotomy may be used to afford width and mobility in the web space.

Amputation proximal to the neck of the first metacarpal leaves a stump that is limited in grasp and pinch. There are only two solutions: to provide a stump with an adequate covering of durable, nonadherent, painless integument with the ultimate goal of adapting a thumb prosthesis; or, if necessary, to reconstruct a new thumb.

In reconstructing a new thumb that will be useful, one must provide the thenar pillar with length, mobility and good sensation. This is accomplished best by transplant of the index or the middle finger to the thumb. These are technical procedures, the detailed description of which is beyond the scope of this chapter. When the index finger is used, a modified Z-plasty is employed. The digit is transferred, complete with muscle, nerve, tendon and blood vessels, to the shaft of the first metacarpal, at the same time being rotated 90° so that the pad of the "thumb" created by the transplanted index finger will appose the remaining fingers. Tendons are

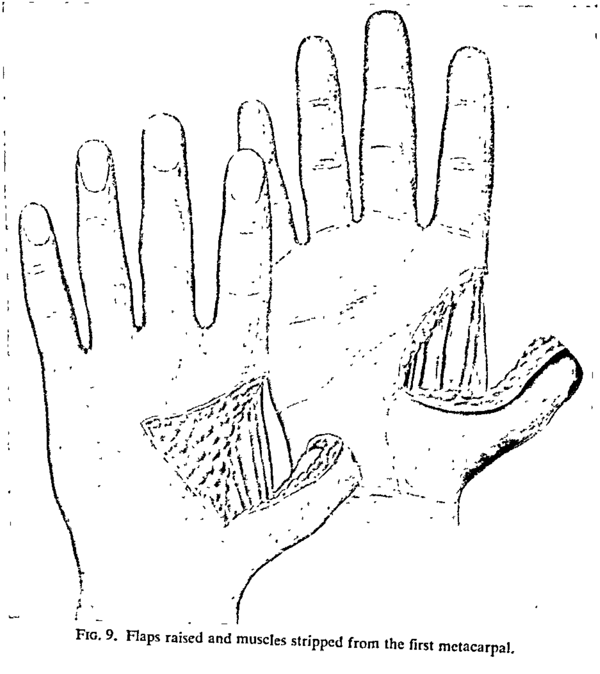


FIG. 9. Flaps raised and muscles stripped from the first metacarpal.

transplanted to substitute the necessary mobility of the thumb. When the middle finger is to be substituted, the Hilgenfeldt method may be used. In this procedure the dorsal attachments of the extensor tendons are severed and a palmar pedicle of skin, tendons, nerves and vessels, with the finger attached, is transferred radially as a whole. J. Böhler has modified the latter procedure in transplanting the middle finger to the thumb. In addition, he moves the index with its metacarpal to the position of the transplanted middle finger. This provides a wide, mobile web space and good strength and mobility in lateral pinch and grasp. The cosmesis is excellent. As for the technic: an incision is made about the base of the finger and the extensor tendons are divided; then, through an S-shaped incision in the palm, a pedicle, consisting of the digital nerves and vessels, is formed with the middle finger remaining attached to the pedicle. A subcutaneous tunnel is created on the thenar eminence through which the middle finger, its flexor tendons and neurovascular pedicle are passed. Bony fixation then is secured to the first metacarpal at the desired level. The extensor tendons, which were divided prior to

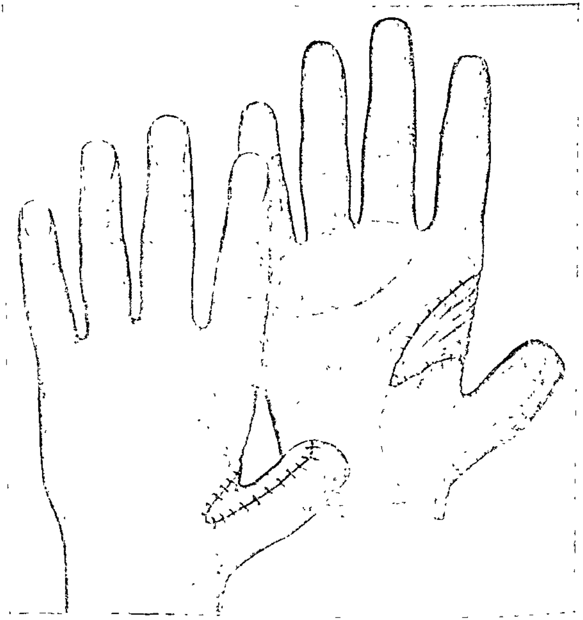


FIG. 10. Closure completed.

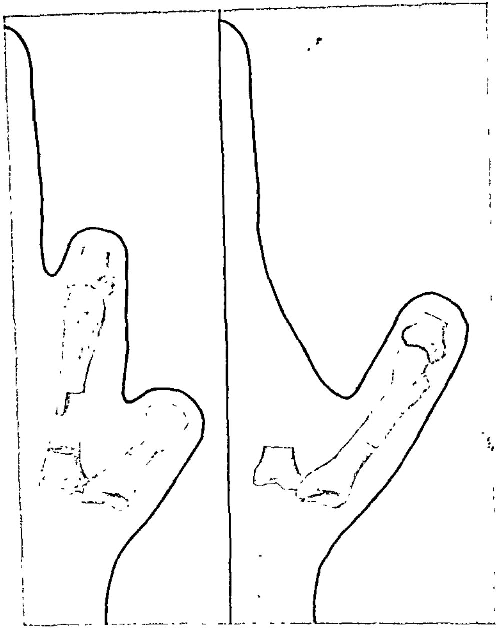


FIG. 11. Transplant of index finger to thumb. (*Left*) Before transplant. (*Right*) After transplant. (Step cut indicates 90° rotation of transplanted finger.)

transplant, are attached to the thumb extensors: the short extensor of the thumb is atached to the middle slip of the extensor aponeurosis of the transplanted finger, while the long extensor is attached to one of the lateral slips. For cosmetic reasons the transplanted finger is shortened to approximate the length of the thumb. In cases in which the third metacarpal has been removed, the index finger with its metacarpal is shifted to the third metacarpal base. While these are rather formidable procedures, they may be extremely valuable, especially when the opposite extremity has little or no function.

Replacement of the thumb by osteodermal graft is not a desirable procedure, because usually the function is poor, due to lack of circulation and sensation. It is indicated only to salvage what otherwise might be a totally useless hand. It is carried out by reconstructing a tube-pedicle graft that is transplanted into the base of the thumb. Into this a bone graft is inserted with its proximal end fixed to a remnant of the first metacarpal or to the greater multangular bone.

MULTIPLE-FINGER AMPUTATION

When amputation of more than a single digit is imminent, the problem of functional reconstruction of the injured hand is vastly greater than that which presents itself in the loss of a single ray. Similarly, if the loss is to

FIG. 12. Transplant of middle finger to thumb by Bohler modification of Hilgenfeldt operation Note transplantation of index finger to the position of the middle finger. (Dr. J. Böhler)

take place at the level of the fingers, the situation is more complicated with the loss of each successive finger; if the loss includes both the fingers and their accompanying metacarpals, surgical rehabilitation will require still more thought and planning if maximal use is to be attained. The functional objective of creating a prehensile tool of infinite dexterity remains unchanged, but the manner in which the three primary functions of the hand—grasp, pinch, and hook—may be preserved and modified according to the dictates of anatomic necessity is compounded with each successive degree of tissue loss. It is the purpose here to outline some of the standard situations that may be encountered and to present the surgical considerations that form the guide to treatment. Fracture and skin coverage per se are not dealt with here, since they have been considered exhaustively in the writings of others; however, their value in preserving remnants of the hand is so great that this must not be attributed to error of omission but rather to the limitation of space

The methods employed follow the general dictum that all serviceable tissues should be retained. It should be reiterated that often this is possible only at the time of initial surgery and that the thoughtful hand surgeon will utilize the best in orthopaedic and plastic concepts to gain this end Each phase of reconstruction that may be accomplished safely at the first surgical episode will lessen the inroads of scar tissue that binds down the tissues, restricts their mobility, adds to discomfort, and affects the appearance of the hand. It must be added that much of the appearance of the hand is dependent on mobility and dexterity, for the suggestion of normalcy is created by changing form in movement.

The problem of multiple-finger amputations presents so many facets that it would be impossible to present each in detail here. Therefore, it is the purpose to present some of the combinations of amputated digits that occur frequently and the general principle that each involves.

The general objectives are (1) to salvage remaining digits and digital remnants; (2) to save as much length as possible in the remaining fingers; (3) to preserve the palm for stability of grasp, pushing and holding; (4) to provide an adequate cleft between the thumb and the remaining fingers, (5) to furnish two poles for pinch and grasp, consisting of a thumb or thumb substitute and finger or finger substitute; (6) to ensure the approximation of these two polar elements by increasing their mobility and supplying motor elements when necessary and by changing their position through osteotomy.

When the index and the middle fingers (or

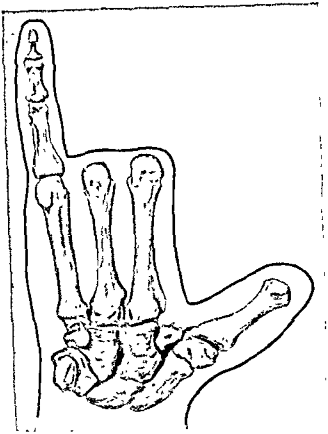


FIG. 13. Excision of the second metacarpal will create an adequate thumb cleft in cases where the little finger remains and all other fingers are disarticulated at the metacarpophalangeal joints.

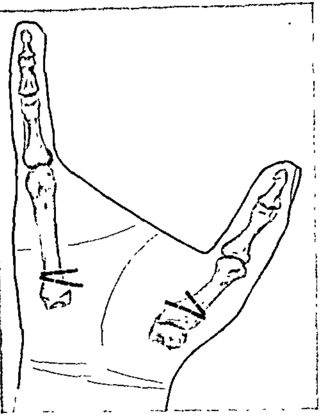


FIG. 14. When the thumb and the little finger alone remain but cannot be approximated, an osteotomy of one or both bones near their bases and angulation of the fingers toward one another will facilitate this action. If power is lacking for this action, a tendon T or opponen's transplant may be added to the operation.

index, middle and ring fingers) are amputated and the thumb and the ulnar fingers are intact, no special problems are present at the finger level provided that the stumps of the amputated fingers are sound. The little and the ring fingers afford fair stability for grasp so long as the palm and the remaining finger stumps are intact. An adequate cleft usually is present between the thumb and the fingers, since the palm and the thumb web generally are not involved. No special treatment is required. When amputation occurs at the level of the metacarpophalangeal joints, stability is decreased and there is more likelihood of damage to the web space. Often the palm is not affected and should not be disturbed because of the stability it affords grasp Pinch may be accomplished readily by the apposition of the thumb and the remaining ring and little fingers. When amputation occurs at the level of the metacarpal shafts, or proximalward, the problem is principally one of making a smooth, even sloping contour between the thumb and the remaining ring and little fingers. To create such a web, often it is necessary to free it of projecting bone by completely excising the remaining stump of the second metacarpal. The suture line never should cross the web transversely from the ring finger to the thumb. This type of closure invites contracture with narrowing of the web and drawing of the thumb toward the remaining fingers so that the span of the hand is decreased. In this instance, closure must be of the zigzag type, multiple Z-plasties being utilized as necessary so that the web will remain freely mobile. So far as the remaining ring finger is concerned, it is well to be sure that the interosseous muscle providing its radial deviation is adequate

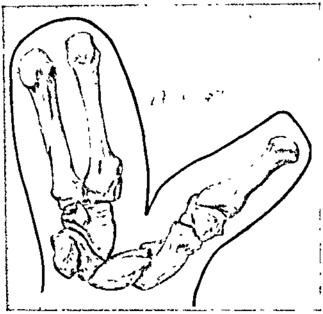
for lateral pinch and to reinforce this action by tendon transplantation as required. The third metacarpal forms the base for attachment of the adductor tendon of the thumb as well as the pivot point about which the ring and the little finger rotate in creating the palmar arch. When intact to the level of the transverse metacarpal ligament, it should be maintained; if not, the shaft should be beveled to ensure a smooth web space.

When the thumb remains intact and all fingers are amputated at the level of the metacarpophalangeal joints, the problem facing the surgeon is to provide a cleft in the web space between the thumb and the remaining fingers of sufficient depth to give greater mobility to the fifth metacarpal and still to maintain adequate palm for palmar pushing and lifting. Since the fingers are not long enough to appose the thumb with ease in pinch or to hold objects against the palm in grasp, it is desirable to increase the *width and the depth of the web. This is* accomplished by amputation of the second metacarpal. The third metacarpal is not disturbed, because it forms the center of rotation for the palmar arch. It is well to ensure the mobility of the fourth and the fifth metacarpals by attaching the extensors and one of the long flexors to the metacarpal heads of these two bones. If the surgeon fails to do this, the fourth and the fifth metacarpals will not roll toward the thumb in pinch and grasp. When the third, the fourth and the fifth metacarpals are left adequate, palm remains for pushing and palmar lifting.

When the thumb remains, the second metacarpal is amputated at mid-shaft, and the middle, the ring and the little fingers are amputated at their metacarpal heads, the problem is one of clearing the web space by resection of the second metacarpal and making sure that the metacarpals of the fourth and the fifth fingers are powered by the extensors and the long flexors. If the apposition of the fifth metacarpal to the thumb cannot be accomplished well, further mobilization may be carried out by resecting the fourth metacarpal at the metacarpocarpal joint and phalangization of the fifth metacarpal.

When the thumb and the little finger remain intact, and all others are amputated at the metacarpal shafts or bases, the problem is one of apposing the thumb to the little finger. If this cannot be done, the web space is cleared of all impediments and the thumb and/or the little finger are tilted toward each other by osteotomizing the metacarpals at their bases and providing motor power for apposition by an opponen transplant of the Bunnell type or the Bunnell tendon T operation. The usual requisites of these operations are observed with regard to the soft-tissue bed and the strength of the power source.

When all fingers and the thumb are amputated at the metacarpophalangeal joints to form the so-called mitten hand, the problem is to provide apposable posts for grasping and pinching objects. *This is especially important* in the bilateral amputee, in whom the opposite hand cannot substitute for the amputated one and bimanual activities are at their lowest ebb. There are two possibilities for reconstruction of such a hand. First, a two-digit hand may be created, the two apposing poles being represented by the thumb metacarpal and by the fourth and the fifth metacarpals. To do this, the index and the middle metacarpals are removed, and the capitate bone is resected to increase the mobility. Motor power must be furnished these two posts if they are to be of value. A second method of handling this situation is to form a three-digit hand by resecting the index metacarpal and deepening the thumb web and by phalangizing the fifth metacarpal by resection of the fourth at its carpometacarpal articulation. In addition to the creation of a cleft between the middle and the little fingers, the mobility of the fifth metacarpal is increased. Such a three-digit hand has some advantages in that it has pincer action both between the thumb and



FIGS. 15 to 17. Mitten hand (amputation through all metacarpophalangeal joints). FIG. 15. Phalangization to create a 2-digit hand by removing the second and the third metacarpals, together with the capitate bone.

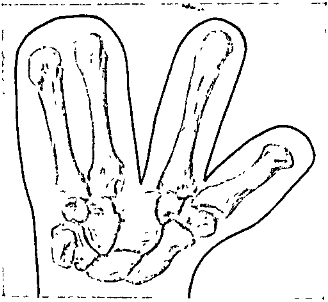


FIG. 16. Phalangization to create a 3-digit hand by removing the third metacarpal. (Modified from Bunnell, S : Artificial Limbs 3:76)

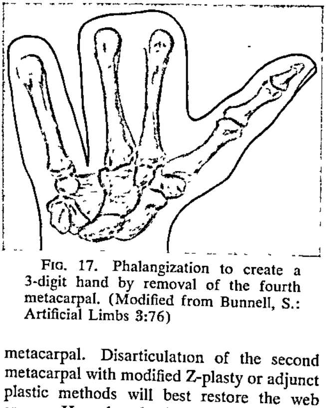


FIG. 17. Phalangization to create a 3-digit hand by removal of the fourth metacarpal. (Modified from Bunnell, S.: Artificial Limbs 3:76)

the middle finger and between the middle and the little fingers.

When the thumb and the index fingers remain, and the middle, the ring and the little fingers have been amputated at the finger level, all remaining fingers should be preserved. If the amputation is at the level of the metacarpophalangeal joints, the metacarpals should not be disturbed, for the preservation of the palm adds much to the hand When the amputation has occurred through the metacarpal shafts, the problem is simply one of providing good sound integument over a rounded hypothenar eminence and a smooth slope between the index finger and the lateral carpus free of underlying bony prominences.

When the ring and the little finger remain, and the thumb and the index and the middle fingers have been removed at the metacarpophalangeal joints, hook action alone remains. The thumb stump is relatively useless, but some function may be restored if a cleft is provided between it and the adjacent metacarpals. This will give some semblance of grasp and increase the mobility of the thumb metacarpal. Disarticulation of the second metacarpal with modified Z-plasty or adjunct plastic methods will best restore the web space. Here lengthening of the thumb is desirable. Since finger transplant is impractical, the only method remaining is to elongate the thumb stump itself. In principle, a transverse osteotomy is made through the distal metacarpal shaft, the distal segment and its investing soft tissues are migrated downward, and a segment of the amputated

second metacarpal bone is interposed to fill the gap.

To permit this downward shift, the incision starts at the posterior aspect of the mid-metacarpal level, swings upward to lie near the metacarpal base at the lateral aspect of the thumb and then passes distally to the anterior aspect of the thumb at a level opposite the starting point. The soft tissues then are mobilized and the interposing graft is placed in position at the osteotomy site, where it is fixed in position with suitable internal fixation such as an intramedullary wire. Next, soft-tissue covering is provided about the transplanted graft and a split-thickness skin graft is used to cover the skin defect left by the downward migration of the skin of the thumb.

When the middle and the ring fingers remain, and the thumb and the index and the little fingers have been amputated, the essential problem is to provide good sound integument and adequate grasping surface, if possible. If the thumb remains at the level of the metacarpal head, this may be accomplished by increasing the depth of the web space by Z-plasty and disarticulation of the second metacarpal at the carpus. When sufficient thumb does not remain, it may be worth while to provide a grasping area between the fingers and the thenar eminence. One method of accomplishing this is through posterior shift of the third and the fourth metacarpals at their carpal articulations and arthrodesis. Since this posterior shift may disturb the tendon balance, tendon lengthening is carried out as necessary.

SUMMARY

The problems of multiple-finger amputations have been discussed at the varying levels at which they are likely to occur. The problem of preserving the elements of the hand for grasp, pinch and hook has been outlined in such a manner as to suggest some of the reconstructive possibilities available to the thinking surgeon. It is well to stress again that often the greatest opportunity for reconstruction is at the time of initial surgery and that an operative plan, covering not only the immediate surgery but possible future functional realignment of the hand, should be formed at this time.

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Amputationes del Digitos e del Mano

Summario in Interlingua

Amputationes que transseca le digitos o le mano non es simplemente un question de distruncation e clausion del vulnere sed de reconstruction secundo un plano formulate

al tempore del operation initial. Viste que le plus grande parte de iste reconstruction pote esser effectuate le melio al tempore del prime session chirurgic, il es importante pro le chirurgo que ille possede un cognoscentia fundamental del function del mano e del principios chirurgic relationate al amputation de illo. Assi motivate, le autor ha dividite su presentation in tres phases: (1) Considerationes functional; (2) le amputation de un sol digito; e (3) le amputation de plure digitos. In le prime de iste tres partes, le problema del function es considerate in le lumine del tres activitates basic del mano, i.e. sasir, pincear, e uncinar. Un evaluation del varie segmentos digital es presentate, tanto con respecto a lor perdita como etiam con respecto a lor a lor effecto super le resto del mano. In le secunde parte, le attention meritate per le varie typos de histo es passate in revista, e iste observationes es applicate al diverse grados de amputation, ab le dissection del puncta de un digito usque al disarticulation carpometacarpal. Es signalate specialmente le desirabile e le non desirabile situationes con referentia al digitos individual. Amputationes digital multiple, discutite in le tertie parte, presenta un problema particular, proque omne caso debe esser tractate individualmente pro satisfacer le requirimentos de omne amputato individual. Es delineate certe principios fundamental que pote esser usate como guida per chirurgos qui se trova confrontate con le problema de iste complexe amputationes.

7

Reconstruction of a Grasping Mechanism Following Extensive Loss of Digits*

ELDEN C. WECKESSER, M.D.†

The fingers and the thumb with their fine, tactile sense and delicate precision movements arising from the broad sensitive palm offer man his greatest means of carrying out the ideas conceived by his mind. The sudden loss of a major portion of this delicate mechanism is irretrievable—one that even the most careful surgery can only modify.

After partial amputation of the hand, the role of the surgeon is that of restorer of all possible prehensile power with sensation of acral parts to as near normal as possible. This involves the rearrangement of the remaining architecture of the injured hand to furnish the individual with movable, sensitive, apposable parts with which he can grasp, pick up and move about the necessary things of life. It is desirable that he be able both to care for himself and to continue as a useful member of society. The vocation of the patient may influence the type and the extent of surgical repair to be undertaken.

TYPES OF PREHENSION

Figure 1 shows some of the basic types of prehension of the human hand. As pointed out by Bechtol,[1] the fine movements of the tips of the fingers and the thumb may be divided into fingertip and fingernail pinch (Fig. 1, *top, left & center*). This may involve the thumb and any or all of the fingers. Lateral prehension between the thumb and a finger is a more secure type of grasp. As pointed out by Hilgenfeldt,[11] this is well exemplified by the grasping of a key between the thumb and the index finger (Fig. 1, *top, right*). This grasp readily allows rotary motion, as in turning a key in a lock. It may also occur between the thumb and any of the other fingers.

In the grasping of larger objects, the fingers may form a hook to support a handle (Fig. 1, *bottom, left*) or encircle and draw the object being grasped against the thumb (Fig. 1, *bottom, center*) or against the base of the palm, the thenar eminence and the thumb (Fig. 1, *bottom, right*).

The top illustrations represent types of fine grip; the lower ones, types of coarse grip. Actually, all combinations of the above are used. For example, in holding a pencil for writing, the tip of the thumb opposes the pencil to the tip of the index finger and the side of the long finger. In holding a screw driver, the handle is secured between the long, the ring and the small fingers, the base of the palm and the thenar eminence. The security of the instrument is enhanced by strong opposition between the thumb and the index finger tips.

* Presented at the meeting of the American Society for Surgery of the Hand held in Chicago, Ill., January 24, 1959.

† Cleveland, Ohio.

INCIDENCE OF INJURY

The hands and the arms are the most exposed parts of the body as the individual operates machines and uses tools and equipment. The National Safety Council statistics for 1958, compiled from 11 states, show that injuries to arms, hands and digits constitute 34 per cent of all industrial accidents. This is higher than for any other part of the body. The high incidence of injuries to the hands, as compared with injuries to other parts of the body, has been pointed out by Bunnell[3] and Rank and Wakefield.[15] During the 5-year period 1952 to 1956, 506 cases were admitted to University Hospitals, Cleveland, for hand surgery. In 21 of these there were extensive amputations of the hand. In short, approximately 100 cases were admitted for hand surgery each year, and of these approximately 4 had extensive amputations of the hand. Undoubtedly the safety programs carried out by industry in the Cleveland area are responsible for keeping this ratio low.

CLINICAL MATERIAL

Including 3 cases prior to 1952, 24 cases of partial amputation of the hand were studied. These cases had complete loss of 2 or more digits or an extensive loss of fingers that was considered to be equivalent to this. The age range was from 3 to 59 years. The average age was 32. There was a predominance (58%) in the 21- to 50-year age group. Three cases had bilateral injury, and 9 had right- and 12 left-hand injury. Among 13 patients who injured one hand, 9, or 69 per cent, injured their major hand. It is not surprising that the hand used more is injured the oftener.

It is realized that the loss of a single finger may handicap a person seriously for certain pursuits and that grasp is altered seriously in

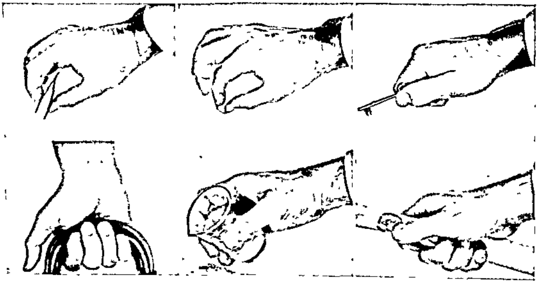

FIG. 1 Types of prehension of the human hand.
(*Top, left*) Fingertip pinch. (*Top, center*) Fingernail pinch. (*Top, right*) Lateral prehension or "key grip" This is firmer and allows ready rotation (*Bottom, left*) The flexed fingers act as a hook to support a handle. (*Bottom, center*) The flexed fingers draw the object against the thumb. (*Bottom, right*) The fingers draw the object being grasped against the base of the palm, the thenar eminence and the thumb, giving the most secure grip of all. It is in the use of large tools, such as the hammer, that the width of the palm is of greatest value in providing a broad base against which the fingers can draw the object being grasped.

all persons with loss of the thumb alone. *However, these problems deserve individual* consideration. The management of associated injuries of remaining digits is not covered here because of limitation of time and space.

Etiology. These injuries reflect the machine age—punch presses, steel rollers, gears, grinders, buzz saws and the like. Power tools and machines that furnish man with the comforts of our age at times work to his destruction. Of the 24 cases studied, 22 were caused by machinery, 1 by frostbite and 1 by a gunshot wound.

CLASSIFICATION OF DESTRUCTIVE HAND WOUNDS

Classification is difficult, since all combinations of injury are possible. However, designation of the portion of the hand destroyed serves some descriptive value and designates which of the major nerves is most likely to be involved.

Radial Border Injury. Greatest injury to thumb and index rays. Median nerve injury most likely.

Ulnar Border Injury. Greatest injury to ring and small rays. Ulnar nerve injury most likely.

Central Injury. Greatest injury to index, long and ring rays.

Complete Destruction. Fingers; fingers and thumb.

PRIMARY TREATMENT OF DESTRUCTIVE WOUNDS OF THE HAND

The great importance of primary treatment ensures its inclusion here. The general principles of initial care of the injured hand have been outlined by Mason,[13] Frackelton,[9] Bunnell,[2] Curtis[8] and others.

Frequently, injuries in which a part of the hand is lost leave the remainder of the hand so disorganized that the surgeon hardly knows where to start in his attempt to salvage functional parts The skin may be torn away and every remaining tissue damaged (see Fig. 6, *top, left*). However, we know that great reparative powers exist if an adequate blood supply remains. The first requirement, then, is one of circulation. This being present, the general plan of procedure of an experienced surgeon interested in hand surgery should be somewhat as follows:

1. General or regional anesthesia in the main operating room.
2. Mechanical cleansing of surrounding skin and nails.
3. Gentle irrigation of the wound proper with normal saline.
4. Assessment of the extent of injury.
5. Removal of devitalized tissue and foreign bodies.
6. Alignment of fractures.
7. Nerve repair.
8. Tendon repair in the more favorable cases.
9. Skin coverage: primary closure, flap rotation, free grafting, pedicle flap.
10. *Immobilization in position of function when possible.*

Primary closure or coverage during the first 4 to 6 hours is most important, and immobilization, elevation and antibiotics should be almost routine, as well as immunization against tetanus. Thus, swelling should be diminished and the hazard of infection lessened. Alignment of fractures and fixation with some means, such as Kirschner wires, are highly desirable prior to primary closure whenever possible. There is never a more favorable time to establish a good framework. If the case is an early one and contamination is not great, nerve and possibly tendon repair may be done primarily also. However, the latter frequently can be done with less chance of infection and with a greater chance of success at a later time in the severely traumatized cases.

DELAYED TREATMENT TO IMPROVE PREHENSION

Though good primary treatment in destructive wounds of the hand is most impor-

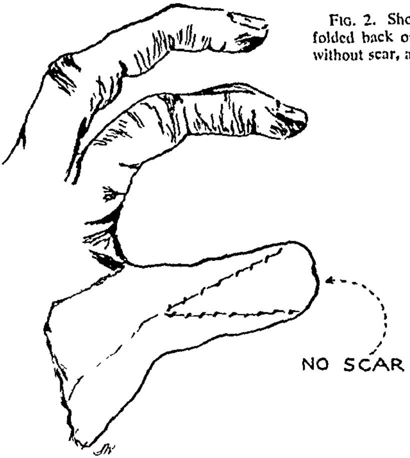

FIG. 2. Showing the distal end of the pedicle folded back on itself. This gives good coverage, without scar, at the tip of the pedicle.

tant, much cannot be done initially and must be carried out at a subsequent time. The delayed procedures that may be of value in improving prehension may be listed as follows:

1. Deepening interdigital clefts: metacarpal removal, Z-plasty, free grafts, pedicle.
2. Strengthening opposition: tendon transfers.
3. Improvement of skin coverage and sensation. rotation flap, graft, neurovascular pedicle.
4. Reconstruction by pedicle flap and bone graft.
5. Rotary angulatory osteotomy.
6. New cleft formation: hand, forearm.
7. Pollicization.
8. Toe transfer.
9. Prosthesis: cineplastic, post, hook.

Deepening Interdigital Clefts

This procedure is one of the most useful means of restoring or improving prehension. It is a comparatively simple method that requires few operative stages. Usually, normal skin can be left within the grasping mechanism for stereognostic sense. Generally, it is employed to deepen the cleft between the thumb and the palm, but it may be used for any other digit as well. Deepening a cleft serves to lengthen the digits relatively and allows greater span for the grasping of larger objects. Often a metacarpal may be removed to widen the cleft further.

This technic is well described by Bunnell[3] and Hilgenfeldt.[11]

Strengthening Apposition

Added strength of grip can be obtained by transfer of tendons from amputated digits. In this way, muscle power, which otherwise would be lost, is used to strengthen apposition. The rerouting of the tendons must be done as indicated in the individual case so as to give the best angle of pull. The oppo-

nens transfer, looping the tendon about the insertion of the flexor carpi ulnaris, has been *most useful. The tendon T and the tendon* loop operations, as described by Bunnell,[3] are also very useful in selected cases. The value of increased strength of grasp is particularly great when the palm is narrowed and the remaining digits are shortened, as is often the case in partial amputations of the hand.

Improvement of Skin Coverage and Sensation

A grasping mechanism is subject to much minor trauma and requires skin tough enough to withstand bumps and scrapes. Sensation serves the dual purpose of protection and stereognosis. The latter is of outstanding usefulness to the individual and is a great advantage over an artificial hand. How to keep or to bring normal skin within the grasping mechanism is one of the important problems facing the hand surgeon. Often this can be done by flap rotation or, *less frequently, by neurovascular pedicle* transfer.[12] By these methods, sensitive skin can be placed in the areas where it will be utilized best and the balance of skin coverage made with free graft or pedicle flap. Of course, anesthesia due to nerve division requires nerve repair.

Reconstruction by Pedicle Flap and Bone Graft

The restoration to function of the remaining traumatized portions of a partially amputated hand may not suffice to give the patient grasp. Then, in selected cases the building up of a part or parts of the residual portion of the hand may be very useful. This becomes particularly true when all digits have been amputated or the thumb has been destroyed. This technic requires staged procedures, which are time consuming both for

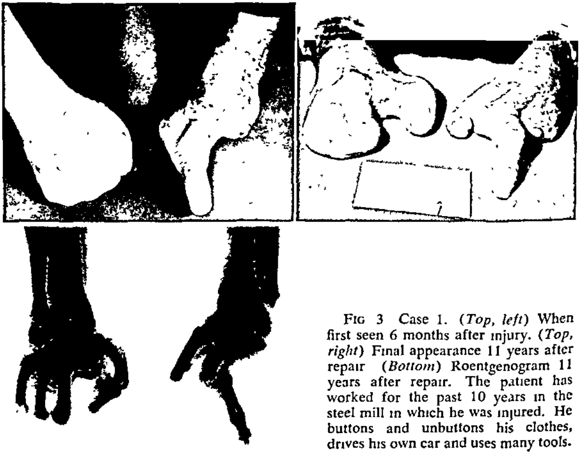

Fig 3 Case 1. (*Top, left*) When first seen 6 months after injury. (*Top, right*) Final appearance 11 years after repair (*Bottom*) Roentgenogram 11 years after repair. The patient has worked for the past 10 years in the steel mill in which he was injured. He buttons and unbuttons his clothes, drives his own car and uses many tools.

patient and doctor. However, in our experience, the results have justified the means. We have preferred the use of abdominal tubed pedicle flaps, usually prepared prior to attachment and bone from the iliac crest.

Sometimes sensation of the pedicle tissue is not good, and difficulties with open ulceration have been reported.[4] The latter has not been a problem in our hands. In the construction of a post for apposition, it has been our custom to form the free end by folding over the pedicle distally, so as not to leave a scar at the tip (Fig. 2). This gives tougher coverage at the tip with less likelihood of ulceration. Bunnell recommends keeping the reconstructed structures short.[4] Whenever possible, normal skin should be used on apposable surfaces to give stereognosis, as mentioned previously.

Rotary Angulatory Osteotomy

This procedure, recommended by Bunnell[3] and by Onne[14] is most useful when remaining digits do not meet. By changing the plane of flexion of a remaining digit, better opposition can be obtained in selected cases. This is particularly true when the central digits are lost and the central metacarpals are retained. Usually, the osteotomy is made at the base of the metacarpal of the remaining ray whose direction is to be changed, unless a fracture exists at another level. Grasp can be improved very greatly by this method, though narrowness of the grasping mechanism may still be a problem if several metacarpals were lost.

New Cleft Formation

This procedure involves making a cleft where none existed previously. In the hand, this involves the removal of a metacarpal, as described by Bunnell.[4] The fourth or the fifth metacarpal having mobility at the base can be used for apposition when the first is missing if proper tendon transfers are carried out to supply strength of grip. In the forearm, the Krukenberg cleft between radius and ulna has been reported to be useful, especially in blind persons.[3,5] However, the cosmetic result is not good.

Pollicization

Rotation of a finger to thumb position in cases of loss of the thumb has proven to be useful. This may be the adjacent finger or the long finger.[11] Amputation of the tip of the transplanted digit has been performed by Littler[12] to make it of more suitable length for apposition with the other fingertips. At present, the author is reserving this procedure for a case in which the thumb was amputated completely and the index finger injured. Observation of several individuals with thumb amputation who have made dexterous use of their index fingers in the normal position have made him hesitant of risking impaired movement and sensation in a transplanted position.

Toe Transfer

The transfer of a toe to replace a digit on the hand was first reported by Nicoladoni in 1900. Clarkson[7] and others[6,10] have recently reported favorably on the procedure, though movement and sensation of the transplanted digits have been a problem.

Prosthesis

An artificial appliance does not have sensation, it wears out, and it is a nuisance to apply and to keep in repair. In spite of all these objections, many are very useful and the best that can be accomplished when no grasping mechanism can be reconstructed. The artificial post to appose normal fingers has the advantage of sensation in a part of the grasping mechanism.

For the workingman with complete amputation of the hand, the hook is still the most practical, either with shoulder harness or cineplasty. The Army Prosthetic Research Laboratory's mechanical hand with cosmetic glove looks better and is very useful. In suitable cases, cineplasty allows opening and closing of the hook or hand without moving the arm or opposite shoulder.

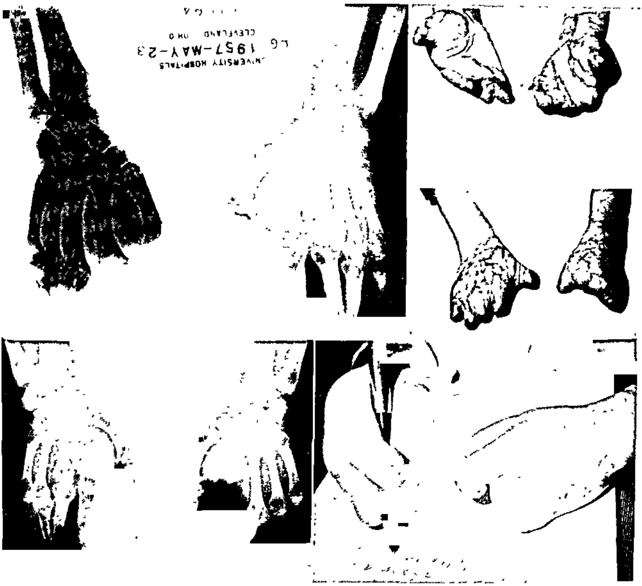

FIG 4 Case 2. (*Top, left*) Appearance roentgenographically when the patient was first seen 3 months after injury. (*Top, right*) Excellent primary treatment by free grafting has given primary coverage. (*Bottom, left & right*) Appearance after reconstruction The patient now handles medium-sized objects quite well He dresses himself, drives his own automobile and is back at work at the steel mill running a conveyor.

CASE REPORTS

The author now summarizes 14 cases of partial amputation of the hand with which he has been concerned.

Case 1. A 49-year-old white man had both his hands caught in a punch press while working in a steel mill February 22, 1947 All the fingers of the right hand were amputated at the metacarpophalangeal joints and the thumb at the interphalangeal joint The hand was a congealed club with no method of grasp The left hand showed a retained index finger with the thumb amputated through the metacarpal and the balance of the hand off through the carpus.

Figure 3, *top, left*, shows the condition of the patient's hands when he was first seen 6 months after injury. He could hold objects only by pressing his hand stumps together, and he was quite helpless

By means of 8 operations over the following 9 months pedicle flaps from the abdomen were applied to the thumb areas of each hand. On the right, the index metacarpal was removed and a free skin graft also was used to give a deep cleft with a span of 1½ inches (Fig 3, *top, right*).

Adduction of the thumb was strengthened by attachment of 2 flexor tendons of the amputated fingers. An iliac bone graft was inserted into the pedicle on the left thumb to give a post for apposition to the remaining index finger. This provided grasp for objects of small and medium size for both hands. The grasp span is 2½ inches on the left.

Figure 3, *bottom*, is the roentgenogram taken in October 1958, 11½ years after injury. A severe post-traumatic arthritis of the proximal finger joint is seen with ulnar luxation of the digit. However, the patient has useful painless motion and grasps strongly with his hands.

He dresses himself, he buttons and unbuttons his clothes, and he has been back at work at the steel mill for the past 10 years He drives his own automobile and is self-sufficient. He uses a hammer with both hands and can drive spikes. The pedicle tissue of the thumbs has worn well. Protective sensation has returned. There has been no difficulty with ulcerations. His only complaint is that he sometimes gets a callus on his right thumb pedicle.

Case 2. A 43-year-old white man had both hands caught in steel-mill rollers February 20, 1957, when he was attempting to remove an irregularity on one of the rollers with a file. The rollers were moving toward him, but as he pressed the file against them his hands were carried under the lower one and caught between it and the frame of the machine. There was extensive avulsion of the skin, as well as amputation of all digits of both hands. The amputations on the right were through the proximal phalanges and on the left somewhat more proximal (Fig. 4, *top, left*). His wounds were well covered with free skin grafts when he was first seen 3 months after injury. Figure 4, *top, right*, demonstrates excellent primary treatment. However, he was unable to grasp with either hand because of lack of apposable parts on his hand remnants.

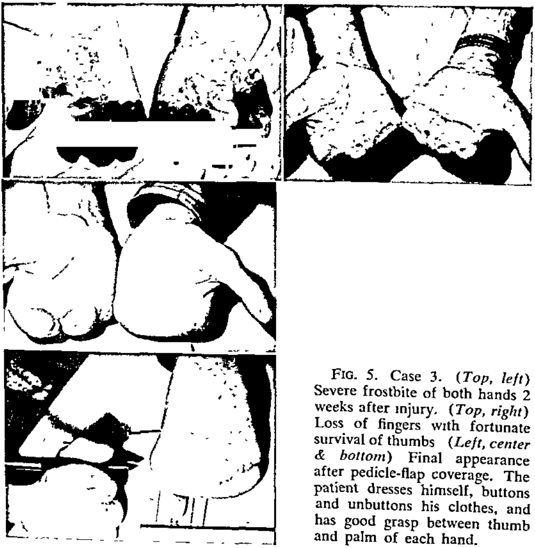

FIG. 5. Case 3. (*Top, left*) Severe frostbite of both hands 2 weeks after injury. (*Top, right*) Loss of fingers with fortunate survival of thumbs (*Left, center & bottom*) Final appearance after pedicle-flap coverage. The patient dresses himself, buttons and unbuttons his clothes, and has good grasp between thumb and palm of each hand.

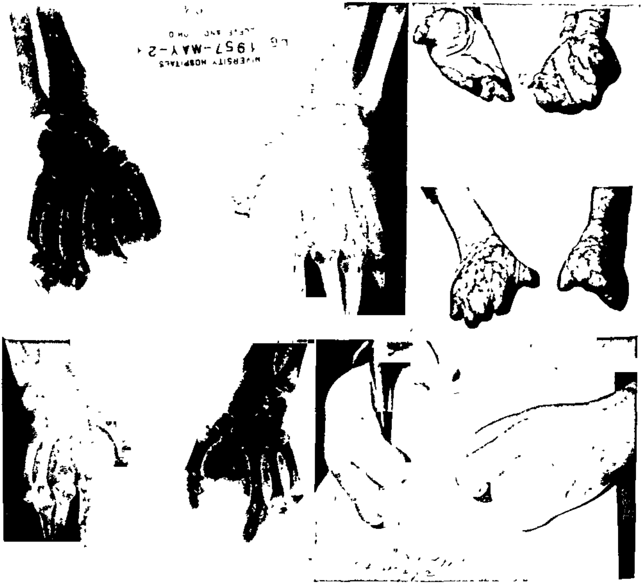

FIG. 4. Case 2. (*Top, left*) Appearance roentgenographically when the patient was first seen 3 months after injury. (*Top, right*) Excellent primary treatment by free grafting has given primary coverage. (*Bottom, left & right*) Appearance after reconstruction The patient now handles medium-sized objects quite well. He dresses himself, drives his own automobile and is back at work at the steel mill running a conveyor.

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By means of 8 operations over the following 9 months pedicle flaps from the abdomen were applied to the thumb areas of each hand. On the right, the index metacarpal was removed and a free skin graft also was used to give a deep cleft with a span of 1½ inches (Fig. 3, *top, right*).

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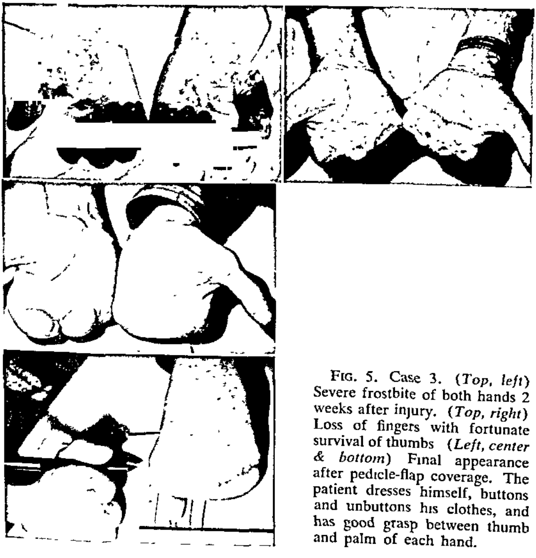

FIG. 5. Case 3. (*Top, left*) Severe frostbite of both hands 2 weeks after injury. (*Top, right*) Loss of fingers with fortunate survival of thumbs (*Left, center & bottom*) Final appearance after pedicle-flap coverage. The patient dresses himself, buttons and unbuttons his clothes, and has good grasp between thumb and palm of each hand.

By means of 12 operative procedures during the next 13 months, abdominal pedicle flaps were applied to each thumb stump; and these structures then were lengthened by iliac bone grafts. The index finger on the right hand was lengthened likewise. On the left hand, the index metacarpal was removed to deepen and broaden the cleft between the thumb and the long finger metacarpal, and the latter was lengthened with an iliac bone graft. The appearance externally and roentgenographically is shown in Figure 4, *bottom, left & right.*

Protective sensation has returned completely to the right thumb pedicle, but not completely to the right index tip. On the left hand, protective sensation has returned to the long-finger pedicle except at the extreme tip. The left thumb, which underwent operation most recently, has the least amount of sensory return. Fortunately, normal skin was preserved over the volar surface of the right thumb. The patient now handles objects of medium size quite well. He dresses himself, he drives his own automobile, and he is back at work at the steel mill running a conveyor.

Case 3. A 43-year-old white machinist, struck on the head by a robber, lay in the snow several hours during zero weather in January, 1957. He developed a severe frostbite of all digits of both hands. The appearance 2 weeks later is seen in Figure 5, *top, left.* The fingers were completely lost, as shown in Figure 5, *top, right,* with survival of the thumbs. Abdominal pedicle flaps were used to give good coverage of the areas of amputation (Fig. 5, *bottom*). The patient dresses himself, he buttons and unbuttons his clothes, and he has good grasp between the thumb and the palm on both hands. He is unemployed at present.

Case 4. A 29-year-old left-handed white man had his left hand caught in a blanking press February 8, 1957. All digits were amputated through their metacarpals.

Abdominal tube pedicle flap has been used to lengthen the thumb and the ring-finger stumps, but bone grafts have not yet been inserted. Reconstruction has been delayed because of problems in the patient's home.

[illegible]

admitted to the hospital shortly afterward. Severe mangling injury is shown in Figure 6, *top, left.* All digits were amputated, the fingers at the middle joints and the thumb at the interphalangeal joint. There was severe avulsion of the skin from the balance of the fingers and the dorsum

FIG. 6. Case 5. (*Top, left*) Appearance of left hand shortly after injury in a rolling press. (*Top, right*) Appearance after dermatome skin-grafting and deepening of interdigital cleft between thumb and index finger by Z-plasty and skin graft. (*Bottom*) Final result showing ability to grasp pliers, though the patient was not able to manipulate the tool with his shortened digits.

of the hand. An attempt was made to replace the avulsed skin over the stumps of the digits. This was unsuccessful because of the severe trauma sustained by the skin at the time of injury, and it was later replaced with a dermatome skin graft. Four months later the cleft between the thumb and the index finger was deepened by Z-plasty and dermatome skin graft. The patient then was able to grasp objects of small and medium size and to use his hand quite well. He was able to return to work and has performed his usual tasks as a laborer for the past 4 years. Figure 6, *top, right,* and *bottom,* shows him grasping pliers. However, his shortened digits prevent him from opening the tool in a normal way. Though he can grasp it, actually he cannot use it effectively.

Case 6. On January 23, 1952, a 24-year-old left-handed white man was cleaning the gears of an operating wallpaper printing press with a cloth. The cloth caught in the gears, drawing his left hand in with it. The index and the long fingers, as well as the carpal bones, were lost. Figure 7, *top, left,* is the roentgenographic appearance when the author first saw the patient in November, 1953. The man had already had a long series of operative procedures but was unable to grasp.

An opponens transfer, utilizing the flexor tendons of the amputated fingers, was done in November, 1953 (Fig. 7, *top, right*), and gave excellent results. He has had a strong grip with his left hand between the thumb and the ring finger (Fig. 7, *bottom, left*) and has been employed at his old job for the past 5 years.

Case 7. In May, 1952, at the age of 8, while riding on a tractor with her father, the patient had her right hand caught between a tractor wheel and a metal tool box. The long, the ring and the small fingers were amputated. The index finger and the thumb were preserved. A dermatome skin graft was applied to the ulnar border of the hand July 12, 1952, to provide better skin coverage. Figure 8 shows the girl's ability to write and to play the violin 6 years after injury. Prior to injury she played the piano. After the injury she changed to the violin, with which she has become very proficient.

Case 8. A 49-year-old white man had his left hand caught in a punch press March 8, 1956. All fingers were amputated through the meta-

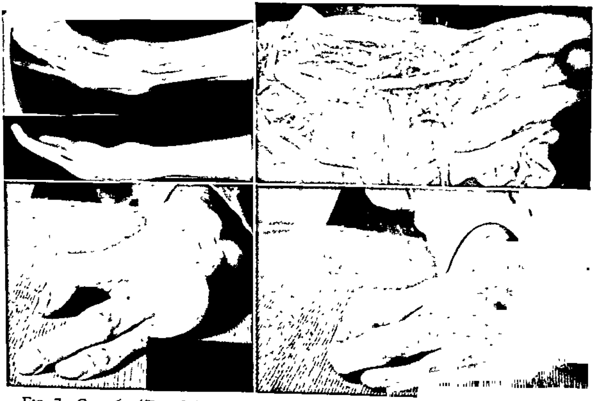

Fig. 7. Case 6. (*Top, left*) Roentgenogram when patient was first seen 18 months after injury. He was unable to grasp. (*Top, right*) Opponens transfer done the same month provided strong grip (*bottom, left & right*). The patient has been back at work at his old job for the past 5 years.

FIG. 8. Case 7. This girl, injured by a tractor wheel, underwent amputation of all but the index finger and the thumb. Six years after operation she is shown (*top*) writing and (*bottom*) playing the violin. She steadies her right hand on the bow by intertwining her thumb in it. This compensates for the lack of width of her palm. She is an accomplished violinist.

arpals and the thumb through the proximal halanx.

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When last heard of, 4 months after the rosthesis was applied, the patient seemed to be etting along well and did not mention pain in is hand stump

Case 9. At the age of 7, this 42-year-old man, who is right handed, had his right hand caught in an ensilage cutter on his grandfather's farm. All fingers and most of the thumb were lost He grasps by flexing the remnant of his [illegible]

salesman.

He feels that any type of prosthesis or reconstruction would be a handicap to him at this late date.

This demonstrates the value of preserving only a remnant of hand, especially in a child

Case 10. [illegible]

Carolina. The small finger and a stump of the thumb remain (Fig. 10). Grasp could be improved here by rotation osteotomy of the remaining small finger to make it oppose the stump of the thumb. Operation is under consideration.

The patient supports his wife and child by doing factory work at present

Case 11. This 73-year-old right-handed man had his right hand caught in a cottonseed press at the age of nineteen All fingers were amputated, and the thumb stiffened in the distal joint (Fig. 11). Grasp could be improved by building a post for the thumb to appose, but the patient is too old for this to be considered.

Case 12. A 60-year-old left-handed man sustained a gunshot wound of the left hand on September 28, 1958. He suffered destruction of the radial 2 fingers and the carpus and compound fracture of the distal radius, with residual bullet fragments embedded deeply in the tissues

Two months later the patient was grasping quite well between thumb and finger. Figure 12 shows him tying his shoelaces

The hand is very useful to him. However,

FIG. 9. Case 9. Demonstrating a most unusal method of grasp by flexing the carpus and the first metacarpal against the forearm. Amputation was done at 7 years of age. This shows the value of saving the carpus and a remnant of the thumb metacarpal in a child.

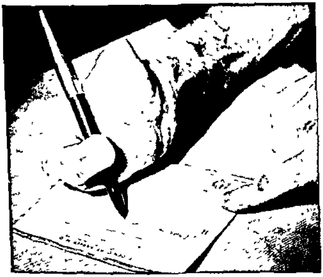

FIG. 10. Case 10 Buzz-saw amputation of all digits except small finger and base of thumb. Grasp could be improved by rotation osteotomy of the small-finger metacarpal to make the small finger appose the thumb remnant.

FIG. 11. Case 11. Amputation of all fingers in a press at 19 years of age. Grasp could be improved greatly by building up ulnar border of hand to appose the thumb.

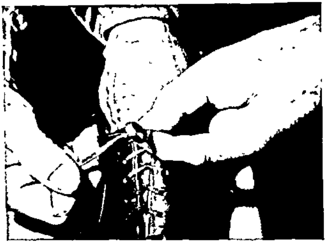

FIG. 12. Case 12. Very useful pinch is demonstrated in this 60-year-old man who lost 3 finger rays and his carpus in a gunshot injury.

lacking a broad palm, many types of objects are less secure in his grasp. More recently, bullet fragments were removed from the wrist because of inflammation, but he is now once again grasping quite well with a span of 4 inches between the thumb and the small fingertip. Because of destruction of the index, the long and the ring metacarpals, the small finger meets the thumb better than it otherwise would, and no rotary osteotomy is indicated. The patient is having some phantom pain in his index and ring fingers.

Case 13. A 20-year-old Puerto Rican had his right hand caught in a punch press August 16, 1953, shortly after coming to the United States. He sustained an amputation of the long, the ring and the small fingers The residual thumb was normal. However, the residual index

FIG. 8. Case 7. This girl, injured by a tractor wheel, underwent amputation of all but the index finger and the thumb. Six years after operation she is shown (*top*) writing and (*bottom*) playing the violin. She steadies her right hand on the bow by intertwining her thumb in it. This compensates for the lack of width of her palm. She is an accomplished violinist.

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The patient experienced severe psychological depression and complained of much pain in the back of the hand that prevented movement of what remained of the thumb Because of continued pain in the hand stump, finally an amputation at the wrist was carried out at the patient's request about 6 months after injury and he was fitted with a No 5X Dorrance hook and shoulder harness.

When last heard of, 4 months after the prosthesis was applied, the patient seemed to be getting along well and did not mention pain in his hand stump

Case 9. At the age of 7, this 42-year-old man, who is right handed, had his right hand caught in an ensilage cutter on his grandfather's farm. All fingers and most of the thumb were lost He grasps by flexing the remnant of his hand against his forearm, as shown in Figure 9. He leads a very active life and plays golf. He is married and has a family, and he works as a salesman.

He feels that any type of prosthesis or reconstruction would be a handicap to him at this late date.

This demonstrates the value of preserving only a remnant of hand, especially in a child.

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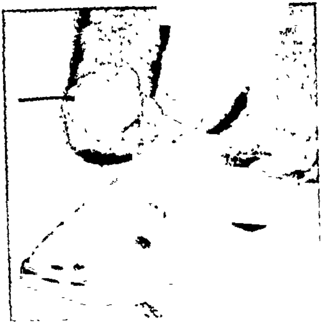

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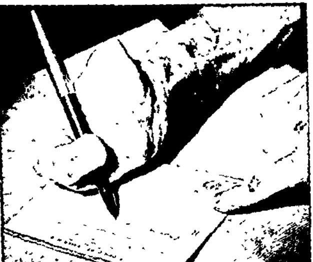

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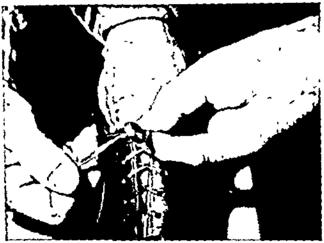

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r had a fracture of its metacarpal and ed extensor and flexor tendons, as well as ed digital nerves.

:rve and tendon sutures were performed in tempt to restore function to the index finger only partial success. The language barrier :nted good patient co-operation. Though tion returned completely to the index :, motion was poor. When last seen, the nt was not using his hand well for grasp. is in marked contrast with Case 7.

ıse 14. A 23-year-old right-handed white lost all the fingers of his right hand in a h press October 6, 1951. The residual b was normal. The index, the long and the fingers were amputated at the base of the mal phalanges and the small finger through ıiddle phalanx.

ven years after injury the patient's wounds all healed well and he grasped quite well een thumb and finger stumps. Flexion of ıiddle phalanx of the small finger was quite l in making grasp more secure. He is still handed.

.e patient now lives in another city and :s his living as a mill man in a lumber mill. operates planes, saws and joiners without ulty. He uses a hammer very well, since alm still is broad. He states, "My hand is eat handicap." However, he does miss the ıal length of his fingers in gripping, espe- in using pliers.

SUMMARY

ıe hand is an organ with great functional ve. Though the loss of any part of it ts in some impairment, the overlap is t enough so that often compensation oc- for most duties. Fine, delicate pinch ements are lost first and the coarser p functions later. To what degree a man ısabled depends on the amount of the l lost and the type of work performed.

breadth of the palm is important ecure grasp of larger heavy objects and ;, but less so for fine fingertip pinch if ıerves, the muscles, the tendons and the s of these fine, delicate movements are ıpaired. The length of the fingers is im- ant in closing about objects of irregular e to produce secure grasp. Shortening he fingers produces lack of in working with tools with movable handles such as pliers, though grasp of stationary objects may be quite good. In its simplest form the apposition of any two parts can provide prehension, as illustrated in Case 9. This demonstrates the value of saving viable parts of the hand.

The upper extremity is the part of the body injured most frequently in industry. The hand that was used more was the one injured in approximately two thirds of the cases. The importance of primary treatment in destructive wounds of the hand is emphasized and outlined.

The various reconstructive procedures have been outlined and discussed. We have found deepening of interdigital clefts, tendon transfers for apposition, improvement of skin coverage and reconstruction by pedicle flap and bone graft to be most useful. The last is of greatest use when the digital amputations are most extensive.

In our experience, digits reconstructed by pedicle flap and bone graft have not ulcerated, and usually they have developed protective sensation. The reconstructed members have been kept comparatively short, and the tips have been formed without scar by folding over the end of the pedicle at the time of construction (see Fig 2).

In regard to the over-all results of the cases presented here, 2 of the 13 completed cases are regarded as poor (Cases 8 & 13). In 1, failure was due to pain in the residual portion of the hand; and in the other, language difficulty and a low threshold of pain prevented active exercise after operation. In the other 11 cases (85%), effective grasp was retained.

CONCLUSIONS

1. Any apposable sensitive portions of the hand can be useful for grasp.
2. Reconstruction of apposable parts of the hand by pedicle flap and bone graft is a useful means of restoring grasp following extensive loss of digits if the parts are kept short.

3. Skin with normal sensation should be brought into the grasping mechanism whenever possible.

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Reconstruction de un Mechanismo pro Sasir Post Perdita Extense de Digitos

Summario in Interlingua

Es presentate un revista de 24 casos de destruction partial del mano human, sequite per un analyse de 14 casos ab le practica personal del autor al Hospitales Universitari de Cleveland Es delineate le varie typos del sasir normal. Es sublineate le valor del extension in longor del digitos pro le action de impugnar objectos de conformation irregular e etiam le valor del largor del palma pro sasir utensiles de grande peso. Le importantia del preservation de omne parte preservabile del mano es signalate. Iste principio es illustrate per le caso de un patiente qui habeva apprendite a tener objectos inter le resto de un prime osso metacarpal e le antebracio.

Es recommendate que le tractamento primari es effectuate per un chirurgo experte qui es interessate in iste problema. Le alineation del architectura del ossos e del copertura cutanee es specialmente importante post disbridamento.

Mesuras de grande utilitate reconstructori es le augmentation del profundor del fissuras interdigital, le melioration del copertura cutanee, le transferimento de tendines, e le reconstruction per pannos pediculate e graffos de osso. Normalitate del pelle es considerate como extrememente desirabile ab le puncto de vista del mechanismo de sasir. Tamen, quando isto non es possibile, digitos de un certe utilitate pote esser reconstruite per medio de pannos pediculate e graffos de osso. Istos debe remaner curte. Es presentate le caso de un patiente, sub observation depost 10 annos, qui ha un utile mechanismo de sasir gratias a digitos coperite con pannos de pelle pediculate. In altere casos presentate, le periodo de observation post-operatori es minus extense.

8

Digital Flaps in Reconstructive and Traumatic Surgery

MICHAEL L. LEWIN, M.D.*

Trauma to the fingers is the most frequent injury encountered in industry and in the home. In the past its treatment was regarded as minor surgery, and many such injuries resulted in permanent disabilities, prolonged morbidity and serious economic loss to the individual, to industry and to society. It has become apparent that these injuries deserve more of the surgeon's attention and skill than they have received until now.

Many injuries to the fingers involve losses of tegumental tissue, which plays an important part in the proper function of the hand. Many manual skills depend on the fine tactile sense of the digits. A workingman's livelihood depends on the unrestricted mobility of his fingers and on stable digital skin that is able to withstand friction, pressure, and the wear and tear to which a working hand is exposed.

The skin on the palmar surface of the hand and the digits has special qualities unmatched by skin anywhere else on the body. It is firm, tough and tightly drawn, and it has a protective cornified layer. It has a compact subcutaneous component. Even relatively small skin losses in this area cannot be compensated for by simple approximation of the surrounding skin. Plastic maneuvers, such as Z-plasty, are useful in preventing contracting scars but have limited application in replacement of tissue loss. The skin of the fingers, particularly of the fingertips, is richly supplied with free sensory nerve endings and the tactile corpuscles of Meissner, which account for its highly developed sensory perception.

Scarring of the fingers may interfere with both motion and sensation. Cicatricial contractures limit freedom of motion. Scarring on the fingertips and on the volar surface produces areas lacking the tactile sense, often unstable and painful on pressure, and interferes with grasping mechanisms and the fine movement of the fingers.

Frequently, losses of skin and subcutaneous tissues are associated with injuries of the underlying structures (nerves, tendons, joints and bones). Repair of the deep structures, either primary or secondary, cannot be done successfully and reliably without adequate provision for replacing the skin and ensuring primary healing.

FREE SKIN GRAFTS

Not every tissue loss on the fingers calls for replacement with a flap. Defects involving the skin alone that leave subcutaneous soft tissue undamaged lend themselves to resurfacing by a free graft, either full thickness or split thickness. Over an adequate soft-tissue pad, these grafts are durable and satisfactory. The return of sensation is prompt; although it may be somewhat in-

* New York, N Y

complete, it is equal or superior to most of the resurfacing procedures.

Full-thickness skin grafts have the advantage of better appearance and more stability than split-skin grafts. In general, they are reserved for elective reconstructive procedures. However, they are also used successfully in earlier replacement of small traumatic losses.

When a definitive resurfacing procedure cannot be used initially, split-skin grafts are used as a temporary epithelial cover. This avoids secondary healing by granulation and minimizes scarring. Thus, the definitive reconstruction can be carried out sooner.

In recent years various composite skin grafts, utilizing selected donor sites, were introduced in reconstructive surgery. Some of these were adapted to reconstructive surgery of the fingers. Since these grafts carry a subcutaneous component, they can substitute for flaps. However, their use is limited to selected cases with limited scarring.

McCash[6] recommended grafts from the toe pulp to fingertips and claimed that they were superior in appearance and sensory regeneration. I have used composite grafts from the earlobe to replace adherent scars on the fingertips. The subcutaneous fat supplies the needed padding, but these flaps are somewhat soft and flabby.

DIGITAL FLAPS

In general, the indication for flap repair is the need of supplying both skin and subcutaneous tissue. Thus, a flap is essential where deep structures need a protective padding and cushioning effect or where adhesions between the skin and underlying structure must be avoided. Flaps should not be used when the surrounding skin is of questionable vitality and primary healing is doubtful. They are also contraindicated when there is a likelihood of infection, which may damage both the recipient and the donor sites.

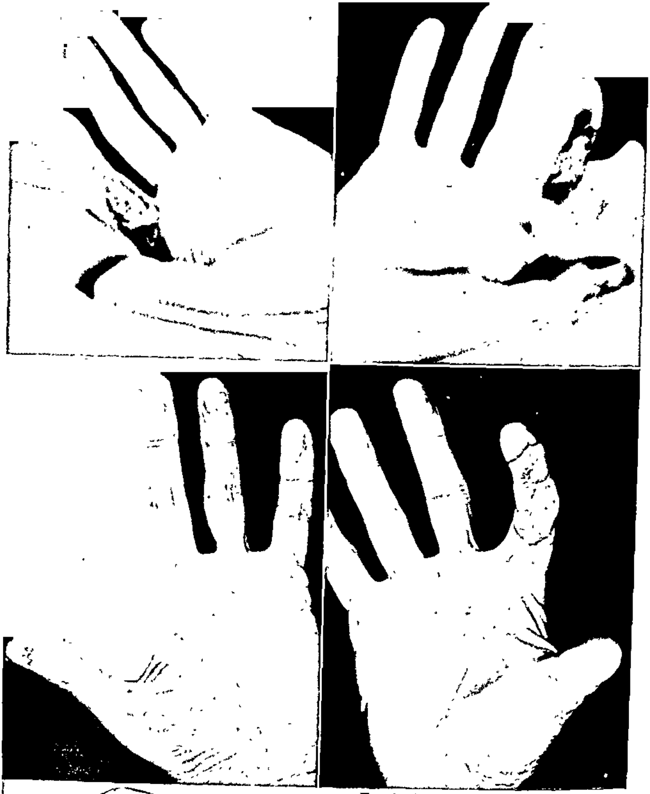
Digital flaps were first introduced into reconstructive surgery for replacement of contracted or painful scars on the volar surface of the fingers.[1,2,5] Many of these disabilities were the result of inadequate early treatment and could have been avoided by the use of these flaps initially. The introduction of digital flaps into traumatic surgery of the fingers proved that they were even more valuable and could be used more frequently than in delayed reconstructive operations.[3,7,8] Reliable and satisfactory results are obtained, with a shortening of the period of disability and with fewer operative stages.

Furthermore, the use of digital flaps widened the scope of traumatic surgery of the fingers. The fact that flap coverage was easily available with simple postoperative positioning of the finger permitted certain immediate repairs of deep structures that otherwise would have been dealt with secondarily. With the change in the conception of primary treatment of finger injuries, such injuries could no longer be considered in the realm of minor surgery. The operating room, rather than the emergency room, became the place for treatment. Such treatment requires sound surgical judgment in the selection of cases, thorough preparation of the wound and an exacting technic of repair.

Finger flaps can originate either from the involved finger (contiguous flap) or from one adjacent to it (cross-digital flap). A rare situation is illustrated in Figure 1, in which a finger flap from the opposite hand was used. One finger had to be sacrificed and another required a flap. Filleting of this finger made available valuable transplantation material.

As a rule, digital flaps are taken from the dorsal and the lateral surfaces of the fingers for replacement of defects on the volar aspect and the tip of the finger. They are also used, though less frequently, for the repair of localized defects on the dorsum of the fingers.

Although the dorsal skin differs in quality from the skin on the volar surface, in practice digital flaps integrate well into their new location, they differ little in appearance from the surrounding skin, and they are durable.



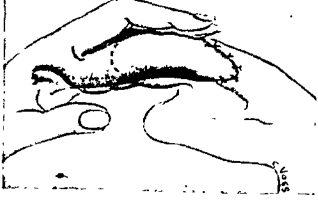


FIG. 1. (*Top, left & right*) Electrical burn of right thumb and index finger and left index finger. Because of destruction of both digital bundles and flexor tendons, the left index finger could not be salvaged. However, there was enough intact skin on this finger to be used for the resurfacing of salvageable right index finger. (*Center, left & right*) Postoperative result, showing flap on right index finger, outlined in ink, and amputation of left index finger. (*Bottom*) Diagram of filleting of left index finger and cross-hand flap to right index finger.

The return of sensation in these flaps is satisfactory; it is better than in abdominal or brachial flaps, though it does not quite reach the normal level. The skin is firm, taut and devoid of excessive bulk. The few hairs sometimes present on the dorsum of the finger are not objectionable when transferred to the volar surface. With constant friction they disappear in time.

The available subcutaneous layer in digital flaps is meager but adequate enough to prevent the flap from adhering and to supply protective padding. However, digital flaps are not bulky enough to replace fully the loss of finger pulp (Fig. 2). And when a flexor tendon graft is contemplated, an abdominal flap with a sufficient fat layer may be preferable to digital skin.

The use of flaps from the same or an adjacent finger simplifies the operative procedure greatly, particularly the postoperative treatment. Little or no hospitalization is required. Postoperative immobilization involves only a part of the hand and avoids uncomfortable fixation, leaving the patient with complete freedom of movement. Secondary operations, such as revisions, defatting, etc., are seldom, if ever, indicated.

The main criticism leveled against digital flaps is that they add to the disability of the injured finger or that they damage a normal finger. Because of the latter consideration, the repair of the donor site merits careful attention. In most cases full-thickness skin grafts, utilizing the thin skin around the inguinal region, are used to resurface the donor sites. They are sure "to take," they contract less than split-thickness grafts, and they blend well with the surrounding skin on the dorsum of the finger. A notable exception is found in Negro patients, who exhibit strong pigmentation in both grafts and flaps. When the graft is placed over a thin layer of areolar tissue, it becomes pliable and freely

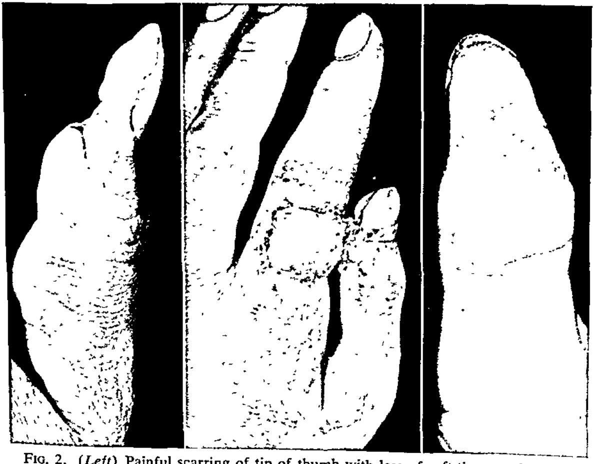


FIG. 2. (*Left*) Painful scarring of tip of thumb with loss of soft-tissue pad. (*Center & right*) Cross-finger flap does not compensate fully for loss of soft tissues, but the result is satisfactory cosmetically and functionally, and probably it is superior to abdominal flap.

FIG. 3. (*Left*) Medical student with multiple lacerations of left index finger, sustained while working with "Do-It-Yourself Kit." Avulsion of skin fragment at level of proximal finger crease, complete severance of flexor profundus and severance of ulnar half of flexor sublimus and digital nerve.

Repair of flexor sublimus, tenodesis of distal fragment of flexor profundus, maintaining slight flexion of fingertip, repair of digital nerve, contiguous digital flap from dorsum, and full-thickness skin graft to secondary defect on dorsum.

(*Center & right*) Result of one operation. Skin graft on dorsum is outlined. Normal appearance of finger. Finger flexes to proximal palmar crease.

movable against the underlying aponeurosis.

As a rule, full flexion of the donor finger in cross-finger flaps is re-established, with the fingertip touching the distal palmar crease. In older patients with a tendency to stiffening of phalangeal joints, some limitation of flexion has been noted. Obviously, these patients would have developed a much more serious stiffening of all the joints of the upper extremity had distant flaps been used.

In traumatic surgery, digital flaps have been used on the following injuries:

1. Lacerations, with loss of tissue in the proximal part of the finger, often associated with severance of a digital nerve or injury to the tendon apparatus (Fig. 3).
2. Loss of the soft-tissue pad on the fingertips over the distal phalanx (Fig. 2).
3. Traumatic partial amputations of the finger (Figs 4 & 5).
4. Localized injuries over the dorsum, with avulsion of aponeurosis or exposure of joints (Fig. 6).

Contiguous digital flaps can be used only over the proximal phalanx and the adjacent part of the middle phalanx. Cross-finger flaps are more versatile and can be used anywhere on the finger.[4] However, their main field of usefulness is in the distal part of the finger, either in avulsion of the finger pulp or in traumatic amputation. In the latter, the use of cross-finger flaps avoids the necessity of further shortening of the digit and does away with the painful scarred stump.

CONTIGUOUS FLAPS

The contiguous flap is obtained from an *area immediately adjacent to the defect* on the same finger. Thus, the operative procedure and immobilization are limited to the injured finger. Postoperatively, the finger usually is held in the functional position of semiflexion. However, it may be immobilized in any other position if the repair requires it. For instance, if the flap is used in conjunction with the suture of a digital

nerve, it may be necessary to immobilize the finger in complete flexion.

The largest available digital flap is one based on the dorsum of the finger along its base and extending distally to the distal finger crease. From one mid-lateral line to the other, such a flap measures approximately 2 x 1¼ inches. This is adequate to

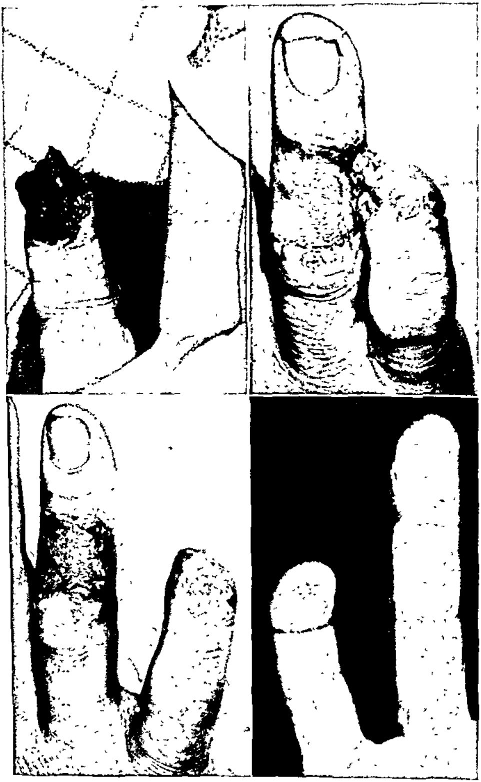


FIG. 4. (*Top, left*) Traumatic amputation of tip of little finger, including the entire nail. Soft-tissue loss extends to distal finger crease. (*Top, right*) Cross-finger flap from adjacent ring finger. Flap fits like a cap over stump of finger (*Bottom, left*) One week after division of flap. With adequate skin graft on dorsum of donor finger, returning stump of pedicle lies in apposition. (*Bottom, right*) Palmar view of little finger with cross-finger flap outlined.

resurface the entire proximal phalanx from the metacarpophalangeal crease to the proximal interphalangeal crease. It is long enough to reach the opposite mid-lateral line.

The skin over the proximal phalangeal joint is included in the flap. In its new location it causes some puckering, but it flattens promptly and is not noticeable. Smaller contiguous flaps may be based distally but not beyond the distal finger crease. They may be limited to the lateral surface of the finger without encroaching upon the dorsum; in

FIG. 5. (*Left*) Avulsion of soft tissue of ring-finger tip in young girl whose finger got caught in an automobile door. The nail is intact, but the bone is exposed. (*Right*) Cross-finger flap from middle finger, with excellent cosmetic result. Flap was sutured to nail.

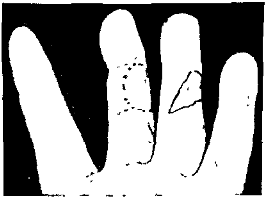


FIG. 6. Arthritic patient, age 65, with dorsal injury of 3 fingers from saw that penetrated deep into bone and avulsed fragments of aponeurosis and joint capsule. Strips of fascia lata were used to bridge the aponeurosis Contiguous flaps from laterovolar surface covered the joints and the fascial grafts. Remaining defect and donor sites resurfaced with free grafts Note that scars on volar surface do not cross digital creases. Free graft on index finger There was some limitation of in finger joints
(*Top, left*)
) Diagram
ng flaps and grafts.

this case the donor area remains entirely inconspicuous (Fig. 7, *top, center & right*).

In special situations, lateral or even volar digital skin may be shifted toward the dorsum. When such flaps are improvised, very careful planning is essential to avoid any detrimental scarring on the volar surface.

PROCEDURES

Contiguous Flaps

Most of the reconstructive surgery of the finger is performed in a bloodless field. When a tourniquet can be placed at the base of the finger, the operation can be performed under either block or general anesthesia. If the defect or the flap extends to the base of the finger, an arm tourniquet is used, and general anesthesia is necessary. In traumatic wounds, careful and thorough débridement is essential.

After excisional surgery is completed, the flap is outlined. It is very helpful to make a pattern of the flap and to shift this pattern back and forth in order to visualize the posi-

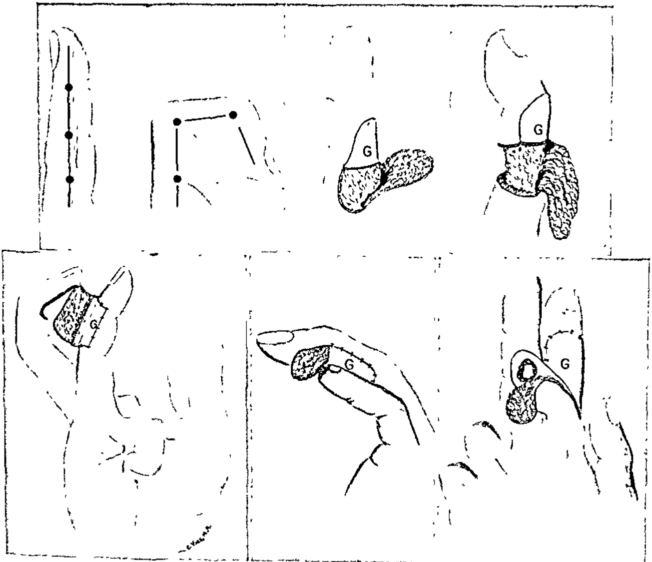


Fig 7. (*Top, left*) Diagram of mid-lateral line of finger. *Scars crossing digital creases anterior to this line will lead to contracture.* The neurovascular bundle runs anterior to this line. (*Top, center*) Small contiguous digital flap from lateral surface of finger (*Top, right*) Large contiguous flap from dorsum. (*Bottom, left*) Cross-finger flap based laterally. Note position of digits when distal part of middle finger is recipient. (*Bottom, center*) Cross-digital flap to fingertip based distally. (*Bottom, right*) Cross-digital flap to dorsal defect over proximal phalangeal joint. *Part of this flap can be returned to its original location when fingers are separated.*

tion of the flap in its new location. This permits placement of the scars in the most desirable position. Frequently, small fragments of skin are excised in order to bring any vertical scars toward the mid-lateral line and away from the volar surface. The pattern is also helpful in ensuring that the flap is of adequate length and width. It may be difficult to visualize the length of the flap necessary to allow for rotation and for the fitting of the flap into the defect without any tension.

The flap is dissected carefully from the aponeurosis, a layer of areolar tissue being left over it. It is freed sufficiently around its base to allow for smooth rotation into its new position. There is always some puckering of the skin (dog-ear) on the side of the pedicle, which serves as a pivot. By undermining the surrounding skin edge, usually it is possible to distribute the skin and avoid puckering. Sometimes an excision of a small triangle of skin away from the base of the flap may be helpful.

The pattern of the flap is used to obtain full-thickness skin grafts from the inguinal region. Both the graft and the flap are sutured with 5-0 silk. While the graft is dissected, the tourniquet is released and careful hemostasis is obtained before the suturing begins. The tourniquet may be replaced and left in place until the dressing is applied. The sutures around the graft are tied over a small stent dressing. Then the finger is immobilized in a functional position with a narrow splint of plaster of Paris or of malleable metal.

After 24 hours the patient usually is discharged with his hand in a sling. The first dressing is done after a week and splinting is discontinued. All sutures are removed in 10 to 12 days, and after 2 weeks the patient is encouraged to exercise the finger.

Cross-Finger Flaps

The preliminary steps are the same as those described for contiguous flaps. Proper planning of the flap is the most important part of the procedure. The flap used most frequently because of its versatility for resurfacing volar defects is one based laterally on the side adjacent to the recipient finger and hinged 180° to face the volar surface. The dorsum of the middle phalanx is the usual donor site, but the flaps may extend throughout the whole length of the finger to the distal finger crease. Such flaps have a broad base, and the blood supply is ensured. Usually these flaps extend from one mid-lateral line to the other.

The relative position of the recipient and the donor fingers is planned carefully and is tested with a pattern of the projected flap. The simplest position is one in which the fingers run parallel to each other. However, frequently it is necessary to flex them in various degrees. This applies particularly to situations in which the distal phalanx of the middle finger is the recipient and has to be brought to the level of the middle phalanx of an adjacent finger (Fig. 7, *bottom, left*).

The flap should reach the defect without tension, about ¼ inch of its pedicle being left unattached. This separates the fingers enough so that a piece of gauze may be inserted between them, and it facilitates the final insertion of the cut edge after dissection of the flap in the second stage.

The full-thickness skin graft is cut according to the pattern and covers the donor area, extending over the pedicle of the flap to be joined to the edge of the defect. A stent is tied over the graft so that the outside dressing may be changed or inspected without interfering with the graft dressing.

The fingers are held together with adhesive strips and a narrow bandage, and are splinted with a narrow volar splint. The uninvolved fingers are not included in the dressing.

After 24 hours the patient is discharged with his hand in a sling and is instructed to keep his hand elevated. After 7 days a lighter dressing is applied. This is changed a few times to avoid macerations. All sutures are removed in 12 days.

Digital in le Chirurgia Reconstructori e Traumatic

Summario in Interlingua

'—tanto contigue (i.e. pren-
ı adjacente al defecto in le
e) como etiam transdigital
' un del digitos vicin) es de
le chirurgia reconstructori e
'itos. Le objectivo principal
es provider pannos de pelle
s dorsal e lateral pro reparar
reimplaciar cicatrices al super-
digito. Le methodo es suffi-
pro esser usate in un
lnerationes tegumental del

amputation traumatic, pannos
presenta un simple methodo
trunco sin le necessitate de
or additionalmente. Le me-
evitar le disveloppamento de
cicatrisate, e insensibile puncta

In multe casos pannos digital rende possibile un definitive reparo primari. Illos pote esser combinate con manovras reparatori in structuras profunde que es usualmente effectuate in vulneres de incision.

Pannos digital es melior in apparentia e resulta in un plus efficace regeneration sensori que non importa qual panno de origine distante. Pannos de origine abdominal o brachial es troppo massive e troppo molle pro le requirimentos del digitos. In plus, lor transferimento es plus complicate e require le pauco confortabile immobilisation del integre extremitate superior, un plus longe hospitalisation, e revisiones secundari.

Pannos digital non resulta necessarimente in notabile defectos functional o cosmetic del digito donator.

concerned, any conceivable amount of tissue needed for finger reconstruction is easily available there, as well as any desired amount of subcutaneous tissue. In fact, it is difficult to dissect flaps thin enough without jeopardizing their circulation. Thus, they are usually too bulky and require secondary defatting operations. The skin over the trunk is mostly thick and soft, with relatively sluggish sensory perception. The sensory regeneration in these flaps, particularly when transferred to the fingertips, is notably poor. As a source of flaps, preference has been for the lower abdomen, around the inguinal region. The skin in this area is finer and thinner than anywhere else on the trunk and is comparable with brachial or submammary areas. However, flaps on the fingers are flabby and soft, and require secondary correction to eliminate the excessive thickness.

The immobilization of the arm in relation to the abdomen for such flaps is less cumbersome and inconvenient to the patient than for any other abdominal or brachial flaps. It permits the patient to be ambulatory after a few days and to get dressed partially, so that he need not be hospitalized during the entire period of immobilization. The required 3-week period of immobilization is of little consequence to the younger patient. However, older patients may have serious complaints of stiffness and pain in the shoulder joint and other joints of the extremities, with occasional permanent disability.

In a search for skin closely resembling the skin of the fingertips, palmar flaps have been recommended. These flaps are applicable only to the distal phalanges of the fingers Thus, their use is limited by the size and the location of the defect, and their scope cannot be compared with that of digital flaps. Palmar flaps call for a skin graft on the donor area, which is the most exposed surface of the palm.

Skin grafts on the palm are quite conspicuous, much more so than grafts on the dorsum of the fingers. The patient often claims disability from the scarring on the palm. Palmar flaps in compensable injuries should be used cautiously.

SUMMARY

The digital flap has become accepted as an efficient, simplified approach to the management of injuries of the finger. Its main value lies in its versatility of application to a large variety of finger injuries, in improved results in both appearance and sensory recovery, and in the simplification of postoperative management.

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late, scar tissue will develop, which may cause irreparable damage. Indications for the use of the different types of skin transplants are outlined in the following pages.

BURNS

The popular methods of treating the burned area are either the pressure dressing or the exposure treatment. The pressure dressing was advocated by Allen and Koch[1] in 1942. The exposure treatment was reintroduced by Wallace,[13] of England, who soon was followed in this country by Pulaski,[10] Artz,[2] Blocker and his associates,[3] and others. Each treatment aims at obtaining a dry wound free of infection and comfortable for the patient. At the present time the exposure treatment seems to be gaining preference. However, it is not the ideal treatment, and for this reason it should not be used exclusively. As a rule, it should not be used at all in the treatment of burns of the hand. A burn of the hand causes an edema that involves not only the skin but the underlying fasciae, tendons and ligaments, predisposing to stiffness and contractures. There is no way of preventing edema with the exposure treatment. The pressure dressing minimizes the development of edema and also permits immobilization of the hand in the position of function. These are two important factors that counteract stiffness and contractures.

The treatment of the burned area starts with proper cleansing. The area surrounding the burn is cleansed with soap and water, while the burned area itself is washed gently with saline solution. Blisters are not opened, since they form a fine protection of regeneration of the epithelium. The area is rinsed with saline solution, dried and covered with petrolatum gauze. Each finger is wrapped separately, then there follows a layer of fluff gauze, which is held in place with an elastic bandage The hand is immobilized in the position of function. That means with the wrist in dorsal extension, the fingers semiflexed, and the thumb in abduction and opposition. The first dressing is changed on the tenth day unless there is evidence of infection. In third-degree burns the eschar is excised daily. If it has not come off completely by the end of the third week, it is excised under light anesthesia, followed by application of normal saline dressings for 1 or 2 days to prepare the area for skin-grafting. Skin-grafting is carried out as soon as the granulations look healthy and are pinkish, flat and free of infection.

DEFECTS OF FINGERTIPS

This very frequent injury often is treated expectantly—in the hope that the wound will granulate and heal. If the defect is only superficial, not exposing the phalanx, the resulting scar may be of good quality. Nevertheless, the healing process is much shortened, and the surface is protected more adequately if it is covered primarily with a skin graft.[7,11,12] In those traumatic defects that result in exposure of the bone, Gatewood[5] and Jones recommend the transfer of a flap from the palm, a simple and highly effective procedure. It provides skin similar to that lost. The cosmetic effect in one of the author's patients was such that the site of the former injury escaped the scrutinizing eyes of three medical examiners. It provides an adequate padding; it shortens the healing period; it makes amputation of the phalanx unnecessary.

Technic

The hand is prepared in the usual way, and the finger is anesthetized by blocking the digital nerves at the proximal phalanx. Procaine, 2 per cent, is used without epinephrine. (The latter may cause gangrene of the finger.) The devitalized tissue is excised. If bone is not exposed, the defect is covered with a full-thickness graft, which is taken from the cubital region of the elbow joint of the same side. The graft is sutured in place. The sutures are left long, a small pad of

9

Plastic Repair of Skin Defects of the Hand

HANS MAY, M.D.*

The mechanized age in which we live accounts for a great number of injuries of the hand. It is estimated that in industry more than one third of all accidents involve the hands. Loss of parts of the hand or of the whole hand, either actual or functional, means in the majority of cases a decrease in the earning capacity of the individual. Hence, the surgeon who undertakes the treatment of a patient with an injured hand has a great responsibility. The initial treatment may decide the functional fate of the hand; therefore, in closed or open hand injuries the surgeon must be familiar with the general surgical principles of treatment, and in surface or compound defects he must know the underlying principles of plastic surgery.

WOUNDS

The therapeutic principles applied to wounds of the hand are the same as for other wounds: converting the contaminated wound into a clean wound; primary closure of the wound if it is treated within the first 12 hours; open surgical drainage if the wound is treated later; followed by secondary closure on the fourth day. Needless to say, proper evaluation of the extent of the injury should precede the repair work.

The contaminated wound is changed into a clean wound by cleansing the surrounding area thoroughly with soap, water and alcohol, and by excision of the ragged wound edges and devitalized tissue. Divided tendons and nerves are sutured primarily unless the wound is badly soiled or contused. However, tendons divided within the flexor sheath of the fingers should only rarely be repaired primarily. The wound is closed with a few interrupted sutures. If large parts of skin have had to be sacrificed or are missing, the defect is covered primarily by skin-sliding or skin transplants, as described later. If the wound is infected, it is only débrided, not excised; and open surgical drainage is applied. Hyaluronidase, which tends to prevent swelling, is injected subcutaneously, except in infected cases: 150 units for each finger, 300 units for the base of the thumb, and as high as 800 units for the palm. In any case, a moderate pressure dressing is applied, and the extremity is splinted with the wrist in cocked-up position, the fingers in semiflexion, and the thumb in semiflexion, abduction and opposition. A useful splint for this purpose is the simple universal hand splint developed by Mason and Allen. Flat splinting of the hand or any of the digits must be avoided at all times. The arm is elevated either on a pillow or in a sling. Tetanus antitoxin and antibiotics are administered.

If a wound has resulted in a defect of the covering tissue, it should be covered with a skin graft or a pedunculated flap immediately following excision of dead tissue, unless the wound is grossly infected. This procedure not only shortens the healing period but also counteracts functional disabilities and deformities. If the defect is left to granu-

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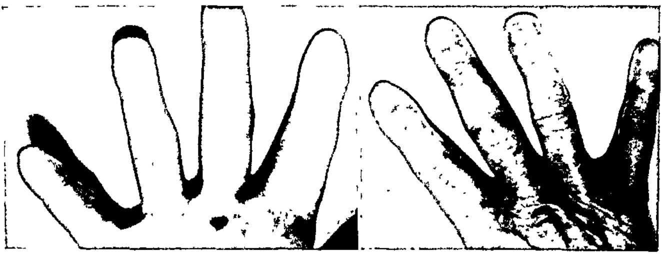

FIG. 3. The pedicle of the flap was narrowed on the eighth postoperative day and severed on the eleventh day, followed by adjustment and approximation of the free edge of the flap and defect edge on the fourteenth day. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

dressing is applied over the immobilized finger, leaving the other fingers free. The wound is inspected 2 days later; the immobilizing adhesive strips may need reinforcement. Ten days after operation the adhesive strips are removed, and the base of the flap is incised from each side under local anesthesia, thus narrowing the pedicle. This step is followed by reapplication of the adhesive strips. On the twelfth postoperative day, the pedicle is severed completely, and the flap is adjusted to the finger on the fourteenth day. This is done by means of a wedge-shaped excision of the raw surface of flap and finger and suturing the wound edges. The raw area at the palm is left to granulate and heals quickly. In none of the author's cases did this area require skin-grafting or skin-sliding.

If the defect involves the volar surface of the terminal phalanx, the flap is constructed so that it opens up laterad or mediad. Such a flap may also be used for small volar defects of the middle phalanx.

LARGE DEFECTS OF DORSAL OR VOLAR SURFACE OF FINGERS

The indications for a graft or a flap are as mentioned in the foregoing; that is, a thick split graft is used if no tendons (naked tendons without tendon sheath) and no bones are exposed. If those structures are exposed, a free graft will not take. Hence, the defect must be covered with a flap.

If the defect is small, transfer of a flap from the immediate neighborhood may be possible. Lewin recommends elevation of a single-pedicle flap (pedicled proximally) from the dorsolateral finger surface; a layer of soft tissue should be left behind to cover the neurovascular bundle and the dorsal aponeurosis. The flap is rotated into the defect, and the resulting secondary defect is covered with a full-thickness graft.

Cronin[4] developed the cross-finger method. For example, a defect of the volar side of the index finger is covered with a flap, which is raised from the dorsoradial side of the third finger and pedicled volarward without injuring the digital vessels and nerves. It is hinged volarward and sutured into the defect of the index finger. The donor area at the third finger is skin-grafted. Usually the flap can be transplanted without delayed stages. A light plaster splint is used for immobilization The flap is severed gradually from its pedicle after 12 to 17 days.

For dorsal defects, if local flaps cannot be used, the pocket flap from the abdomen is recommended (Fig. 5). For volar defects, a single-pedicle flap can be constructed from the same or the opposite side of the abdo-

FIGS. 1 to 3, Case I. FIG. 1. Traumatic defect of tip of fourth finger. Exposure of bone. Conservative treatment for 4 weeks elsewhere was unsuccessful. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

mechanic's waste is applied, and the sutures are knotted over the pad.

In the event that bone is exposed, the finger is bent so that the defect touches the palm, leaving a bloodstained pattern on it. A flap of suitable width and length now is outlined with an aniline dye. The flap is constructed so that the pedicle comes to lie proximally. The important creases of the hand should not be crossed. Next, the donor area is anesthetized, and the flap containing a sufficient amount of subcutaneous fat tissue is raised. After hemostasis, the injured finger is bent, and the peripheral end of the flap is sutured to the dorsal wound edge of the finger; that is, to the nail bed and also to the lateral edges (Fig. 2, *left*). If a long flap is required, the circulation may be insufficient; hence, transfer of the flap should be delayed 1 week by returning the flap to its original site. (In the vast majority of cases, delaying is not necessary since the blood supply is abundant; however, a sufficient amount of subcutaneous fat must be left on the flap.) After the flap is sutured to the finger, the finger is immobilized with adhesive strips, which are passed through an alcohol flame (Fig. 2, *right*). The underlying wound is covered with petrolatum gauze; a gauze

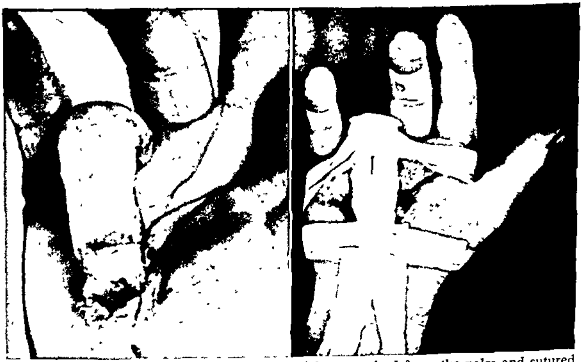

FIG 2 (*Left*) A flap with a proximal pedicle was raised from the palm and sutured to the defect. (*Right*) Immobilization of finger with adhesive strips: one or two running over dorsum of hand and finger to palm; one or two, transversely over finger and just proximal to flap. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

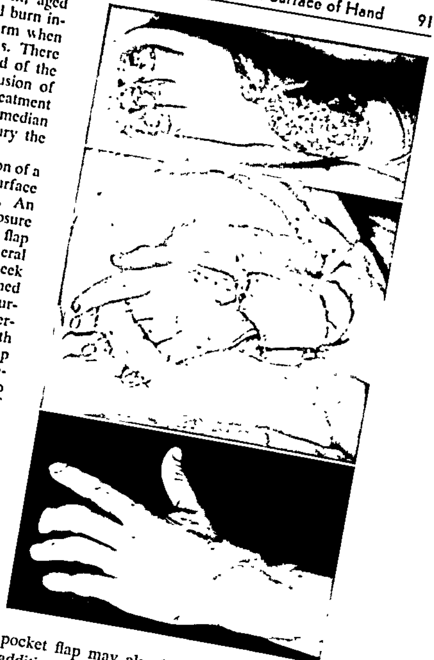

FIG. 5, Case 3. (*Top*) Patient, aged 26, sustained a severe crush and burn injury of the left hand and forearm when the arm was caught in a hot press. There was a fracture in the lower third of the ulna and a hematoma and contusion of the median nerve. Emergency treatment consisted of decompression of the median nerve. Fifteen days after the injury the burn eschar was excised.

(*Center*) Six days later, application of a skin graft to one of the superficial surface defects of the dorsum of the wrist. An abdominal flap was elevated for closure of the main surface defect, but the flap had to be returned, since the peripheral end developed a bluish color. One week later, 3 narrow pocket flaps were formed at the abdomen for coverage of the surface defects over the knuckles of the interphalangeal joints of the third, the fourth and the fifth fingers. The abdominal flap was elevated again. The flap bed was skin-grafted, and the flap was transplanted to the wrist. Seven days later, the base of the main flap was incised on each side, and a laboratory clamp was placed to the middle part. The bases of the finger flaps between 2 fingers were severed, and a small laboratory clamp was applied to the lateral pedicles. All clamps were tightened gradually. Six days later all pedicles were severed. Twenty days later flaps and pedicles were adjusted in place. At the third and the fifth fingers the adjustment consisted of excision of a wedge-shaped piece of tissue at each side of the flap and suturing the edges of the flap to the wound edges of the fingers. At the fourth finger, however, no adjustment of flap edges was made, since they were too short.

(*Bottom*) One year later all flaps were defatted in a 2-stage operation. The median nerve in the meantime had regained full function.

(May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

dunculated flap is the only choice. The flap usually is raised from the same or the opposite side of the abdomen or lower chest, occasionally from the median part of the thigh. The tube flap, being a more complicated method, is not needed for the majority of surface defects of the hand. The larger pocket flap may also be of limited use. In addition to having unquestionable advantages, it has many drawbacks. The tremendous raw surface of the donor site, which after the flap is raised and sutured to the hand comes to lie beneath the latter, causes a great deal of drainage and is a constant threat of infection. Primary closure of the donor wound by skin-shifting or skin-grafting has been unsuccessful in the author's hands.

The author prefers the open single-pedicle flap in the majority of cases. The abdominal flap is used for dorsal as well as for volar defects. If the forearm must be held strongly supinated, a heavy Kirschner wire

FIG. 4, Case 2. (*Top*) Traumatic defect of dorsum of terminal phalanx of left thumb. Note loss of dorsal half of bone of terminal phalanx and exposure of terminal interphalangeal joint. (*Center*) After excision of the wound, immediate transfer of a single-pedicle flap from left upper abdominal wall. The donor area was closed by skin-sliding. Immobilization in a plaster cast. (*Bottom*) Clamping of the pedicle was begun on the ninth postoperative day. The flap was severed on the twelfth day. Eleven days later, the free end of the flap was undercut and sutured to the defect edge. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

men (Fig 4). The flap should be cut as thinly as possible, without, however, endangering its blood supply. The donor site can be closed primarily by undercutting the wound edges and by skin-shifting. To counteract shrinkage, the flap should be made one third larger than required.

Another donor area to be recommended is the forearm or the upper arm of the opposite side The injured hand is laid on the opposite arm, and both are immobilized. Closing the donor site and the need to counteract shrinkage are the same as just described for the single-pedicle abdominal flap. Reid,[11] McCash[7] and others have demonstrated the versatility of this technic. If the forearm must be held strongly supinated, a heavy Kirschner wire is drilled into radius and ulna and left in place until the flap is severed from its pedicle (Howard, quoted by Bunnell). Immobilization and after-treatment are demonstrated by the case reports of Figures 4 and 5.

LARGE DEFECTS OF DORSAL OR VOLAR SURFACE OF HAND

The causes of large surface defects of the hand are manifold. Crushing injuries, avulsion of the skin and severe burns are the common causes. Again, it is emphasized that these defects should be covered as early as possible. For instance, if the injury has resulted in loss of the covering tissue from avulsion of the skin, without exposure of important subfascial structures, the contaminated wound is converted into a clean wound, and the raw surface is covered with a thick split graft. It is advisable to remove the graft in one piece to avoid unnecessary scarring.

In all cases where tendons and other important structures are exposed or will need replacement in the future, transfer of a pe-

FIG. 5, Case 3. (*Top*) Patient, aged 26, sustained a severe crush and burn injury of the left hand and forearm when the arm was caught in a hot press. There was a fracture in the lower third of the ulna and a hematoma and contusion of the median nerve. Emergency treatment consisted of decompression of the median nerve. Fifteen days after the injury the burn eschar was excised.

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FIGS. 6 to 8, Case 4. FIG. 6. Boy, 11½ years of age, lost radial half of right hand as the result of an explosion (*top*). A rather large abdominal flap was transplanted in one stage to provide coverage of the raw surface and an extension to receive later on a bone graft to lengthen the first metacarpal stump. Eight days later the flap was partially separated, and a laboratory clamp was applied to the remaining pedicle to crush the pedicle gradually. Five days later the flap was severed Four days later the flap was adjusted in place (*bottom*). (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

is drilled into radius and ulna and left in place until the flap is severed from its pedicle (Howard, quoted by Bunnell). For defects at the ulnar side of the hand, the flap should be pedicled in the lower portion; for defects at the radial side and the volar surface, in the upper portion. This position of

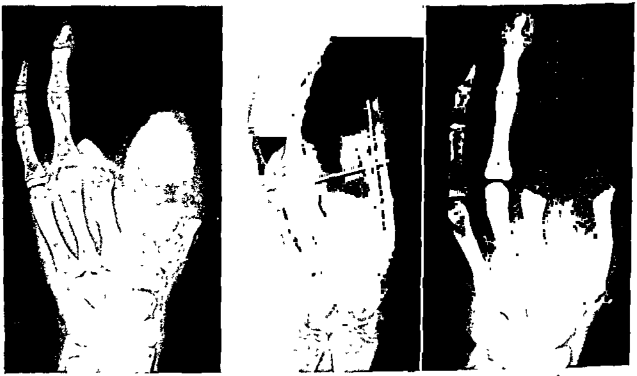

FIG. 7. (*Left*) Roentgenogram of the metacarpal stumps over which the soft-tissue flap is faintly outlined (*Center*) Five months after the flap transfer, a metatarsal bone (the fifth) was placed upon the stump of the first metacarpal bone and transfixed with intramedullary wires (*Right*) Three months later the horizontal cross pin was removed, and after another 3 months the vertical pin (May, H.. Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

the pedicle has some bearing on the circulation of the flaps. The venous return is better in a flap with an inferior—that is, dependent—pedicle and vice versa. Hence, the circulation is more adequate in a flap with a lower rather than with an upper pedicle. This raises the question of immediate or delayed transfer of the flap. If the pedicle of the flap can be made broad—and this can be done often—the flap can be transferred immediately. If the pedicle must be narrow, transfer must be delayed. If delaying becomes necessary in a traumatic defect, the wound of the hand is covered with sterile dressings; a moderate pressure dressing and a splint are applied. If there is no evidence of infection, the dressing is left in place for 5 days. Then it is changed, and the arm is placed in a warm hand bath and active finger exercises are instituted while the hand is in the water. This process should be repeated every day and the splint reapplied each time. Whenever the flap is ready for transfer, it is raised, and, if the circulation remains adequate, it is transferred. However, prior to the transfer of the flap, the abdominal donor wound is skin-grafted. If the flap is still too bulky, more fat is excised from its raw surface. The flap now is sutured to the defect of the hand after the granulations of the wound have been sliced down to their yellow vascular base. The suturing should be done as accurately as possible, particularly if the webs between the fingers need covering. Immobilization and after-treatment are demonstrated by the case reports of Figures 6 to 11.

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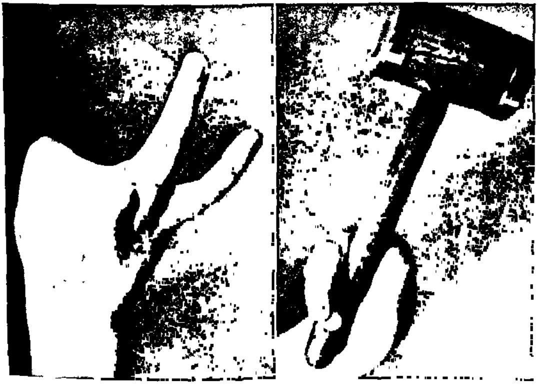
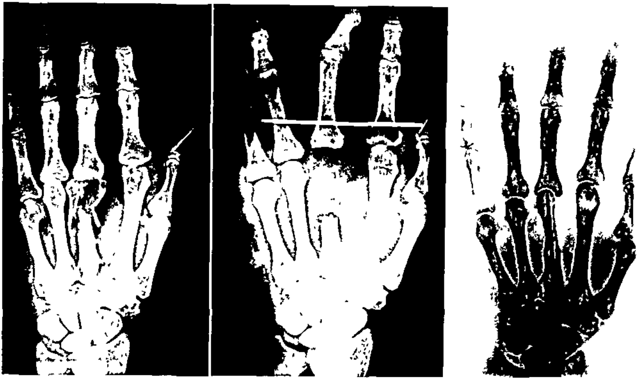


FIG. 8. The functional result (May, H: Reconstructive and Reparative Surgery, ed 2, Philadelphia, Davis)



FIGS. 9 to 11, Case 5. FIG. 9. (*Left*) Patient, aged 62, was shot accidentally in the dorsum of the right hand. The injury resulted in extensive loss of surface tissue and a badly comminuted and compound fracture of the third metacarpal bone. (*Center*) Distal two thirds of the third metacarpal bone was removed. The third finger was suspended upon the first phalanges of the second and the third fingers by cross-pinning. The pin was laid just beneath the webs of the finger and buried subcutaneously. A flap was transplanted from the abdomen in one stage. It was clamped 10 days later and severed 2 days later, and adjusted in place 5 days later (Fig. 10). (*Right*) Three months later the third metacarpal bone was replaced with the fifth metatarsal bone and was stabilized with a longitudinal intramedullary wire and a cross pin through the sides of the metacarpals. This cross pin was removed 5 months later, while the vertical wire is still in place 11 years after the accident. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)

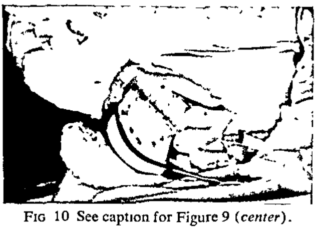


FIG 10 See caption for Figure 9 (*center*).

defect without hospitalization, J.A.M A. 87:1479, 1926

6 Lewin, M L.: Digital flap, J. Plast. & Reconstruct Surg. 7:46, 1951.

7. McCash, C. R.: Cross-arm bridge flaps in the repair of flexion contractures of the fingers, Brit. J. Plast. Surg. 9:25, 1956.

8. May, H.: Closure of surface defects of the hand, Pennsylvania M. J. 49:116, 1945.

9. ———: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis, 1958.

10. Pulaski, E. J, *et al.*: Exposure (open) treatment of burns, U. S. Armed Forces M. J. 2:769, 1951.

11. Reid, J. V., and Harcourt, A. K.: Immediate full-thickness grafts to finger tips, Surg., Gynec. & Obst. 68:925, 1939.

12. Stenberg, G.: Full thickness grafts in finger tip injuries, Acta. chir. scandinav. 99:435, 1950.

13. Wallace, A. B.: The exposure treatment of burns, Lancet 250:500, 1951.

Reparo Plastic de Defectos Cutanee del Mano

Summario in Interlingua

Es discutite le principios general de perditas superficial in le mano ab varie causas traumatic. Le vulneres es claudite primarimente in casos presentate al tractamento intra le prime dece-duo horas. In casos presentate plus tarde, aperte drainage chirurgic es usate, sequite per secundari clausion chirurgic post quatro dies. Tendines e nervos dividite es suturate primarimente excepte si le vulnere es multo immunde o contundite. Tamen, tendines dividite intra le vainas de flexores del digitos pote esser reparate primarimente in rar casos solmente. Ardituras del mano debe esser tractate per bandage de compression e non per le methodo a exposition. In ardituras del tertie grado le partes distachate del eschara ex excidite omne die a partir del remotion del prime bandage, i.e. a partir del decime die approximativemente. Si le eschara non es eliminate completemente al fin del tertie septimana, illo es excidite sub un forma leve de anesthesia, sequite per le application de un bandage salin e graffos de pelle un o duo dies plus tarde.

Si le vulnere ha resultate in un defecto del histos coperiente, illo debe esser coperite de un graffo de pelle o de un panno pedunculate immediatemente post le excision del vulnere, excepte in casos in que le vulnere es inficite grossiermente. Iste mesura reduce le periodo de resanation e contra-age invaliditate e deformitates functional. Si on permitte le granulation del defecto, le formation de histo cicatricial es inevitabile, e isto pote esser le causa de damnos non plus reparabile. Es delineate le indicationes pro le uso del differente typos de transplantation cutanee e le technica a usar in effectuar le varie typos de transplantation de panno pedunculate.

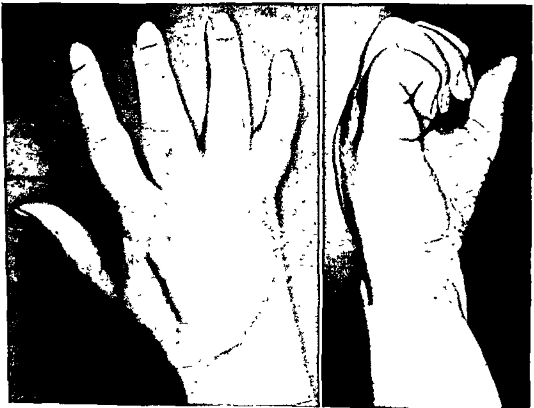
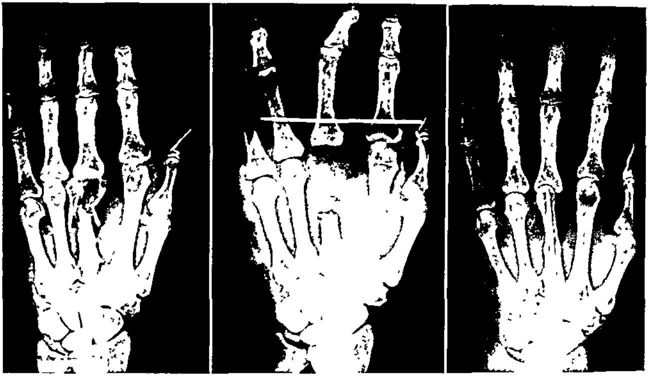


Fig. 11. Functional result. (May, H.: Reconstructive and Reparative Surgery, ed. 2, Philadelphia, Davis)



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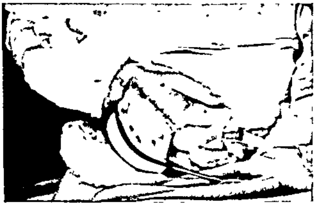

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13. Wallace, A. B.: The exposure treatment of burns, Lancet 250:500, 1951.

10

Congenital Anomalies of the Thumb

ARTHUR JOSEPH BARSKY, M.D.*

The thumb, so frequently involved in congenital anomalies of the hand, is the most important digit. Its function has been estimated as 30 to 40 per cent of the total function of the hand. This chapter deals with anomalies of the thumb.

Comprehensive and valid statistics on the incidence of congenital anomalies of the hand are not available. The best study is Birch-Jensen's *monograph*[5] *reporting* 625 cases, or 1 anomaly per 6,438 persons. However, the most frequent anomalies of all —polydactylia and syndactylia (simple)— are not included in the study; therefore, it is difficult to apply these figures and to interpret them properly. Furthermore, Denmark has a homogeneous population with few foreign-born. The factor of heredity would be more influential than in the heterogeneous population of the United States.

A knowledge of general principles of plastic surgery, including free skin grafts and flaps, is *necessary to do this type of surgery.* It is presumed that the reader possesses this background. Finger incisions should be midlateral but may follow creases. Wherever possible, scars in the areas of tactile, friction or pressure zones should be avoided. Digital nerves in infants' hands are extremely small structures, and often dissections will have to be carried out under a magnifying glass. It is essential that tissue be handled gently to avoid trauma. A pneumatic tourniquet is indispensable. Operative procedures that affect the growth potential should be avoided

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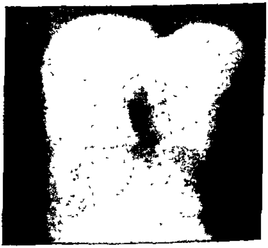
POLYDACTYLIA

Polydactylia is one of the most frequent *anomalies of the hand. Polydactylia on the* thumb side occurs approximately twice as often as polydactylia on the ulnar side of the hand. Males appear to be affected more commonly than females. Often the anomaly is found together with syndactylia, brachydactylia and other congenital malformations

The weight of evidence would indicate a hereditary influence in polydactylia, presumably dominant. However, it does not appear in every generation, and this has been explained on the basis of "lack of penetrance" and genes of different strengths *There may be a recessive type of polydac-*



FIGS 1 to 3. Varieties of polydactylia of the thumb. FIG. 1. Duplication of the distal phalanx. This can be corrected surgically by a wedge excision, ablating the adjoining surfaces of the phalanges and *uniting* the lateral portion of the phalanges, the nail and the soft tissues.

be necessary later on the proximal phalanx, or even arthrodesis, to achieve proper axis.

The surgical treatment of the varieties of thumb polydactylia illustrated in Figures 2 and 3, *left*, present no special problem.

When symphalangism is present, as illustrated in Figure 3, *right*, the obvious treatment is the excision of the fused phalanx, retaining the movable phalanx. Damage to the digital nerve must be avoided, and attention should be directed to realigning the retained phalanx in the proper axis.

SYNDACTYLIA

Although uncomplicated syndactylia is, together with polydactylia, one of the two commonest deformities of the fingers, involvement of the thumb is comparatively rare. However, syndactylia is associated frequently with polydactylia and ectrodactylia. In combinations of these the thumb may be an added deformation.

In our cases, thumb involvement has been mainly in the mitten, or paw, type of syndactylia, the thumb and all other digits present being webbed. The author himself has never seen a case in which *only* the thumb and the adjacent index finger were webbed *except* in the radial group of a cleft hand (Fig. 4).

Syndactylia may be due to an arrest of fetal development at a critical period about the seventh or the eighth week. An interruption of normal development results in persistence of the web uniting the fingers.

Hereditary influence in syndactylia appears to be important. Gates[8] postulated several genetic types. Some may be sex

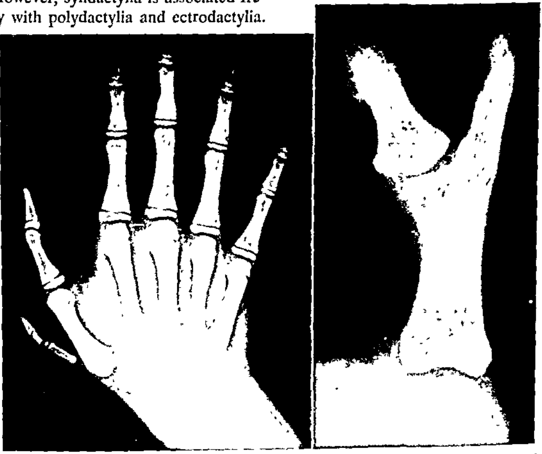


FIG 3. (*Left*) In this variety of polydactylia the accessory digit consists of 2 rudimentary phalanges and a metacarpal attached on the radial side of the normal metacarpal. The surgical removal presents no difficulty. (*Right*) A case of polydactylia with symphalangism. The accessory distal phalanx is fused with the proximal phalanx and extends off the radial side.

Fig. 4. Syndactylia of the thumb and the index finger in a case of cleft hand, a form of ectrodactylia. There is a funnel-shaped defect of the central portion of the hand, with complete absence of the third ray. Syndactylia of the radial and the ulnar groups of digits is found frequently in this type of cleft hand The webbed thumb and index finger should be separated and the digital nerve carefully preserved The denuded adjacent surfaces of the thumb and the index finger should be skin-grafted. If one wishes to correct and close the cleft of the hand, the skin excised from the cleft may be used as a free graft to cover the denuded surfaces of the separated fingers.

Fig. 5. A case of polysyndactylia. Two triphalangeal thumbs are present, with the suggestion of a third on the ulnar side of the thumb group. The remaining digits are webbed, and there is duplication of the phalanges of the little finger. In the surgical repair, extreme caution is necessary to preserve the nerve supply and attachment of tendons.

linked. Males are affected more frequently than females.

A case of polysyndactylia is shown in Figure 5. Two triphalangeal thumbs are present.

Treatment

The treatment of syndactylia is the separation of the digits and restoration of the depth of the web. Incisions on the fingers should be zigzag, and the dissection should be carried deep enough to mobilize and release the thumb in order to bring it into the position of opposition. A free skin graft (or a flap) of generous size and proportion is necessary.

THE "FIVE-FINGERED HAND"

For lack of a more precise expression, this term is used to describe the type of hand that has five triphalangeal digits. The radial digit and its metacarpal lie in the same plane as the other fingers, the thenar muscles are absent, and the radial digit cannot assume the position of opposition (Fig. 6). Although the condition is rare, it can be improved by surgery. A one-stage operation is performed; in this the radial digit is migrated to the thenar region on a neurovascular pedicle, and the metacarpal is shortened and rotated (Fig. 7). This same thumb-substitution operation can be used in cases in which

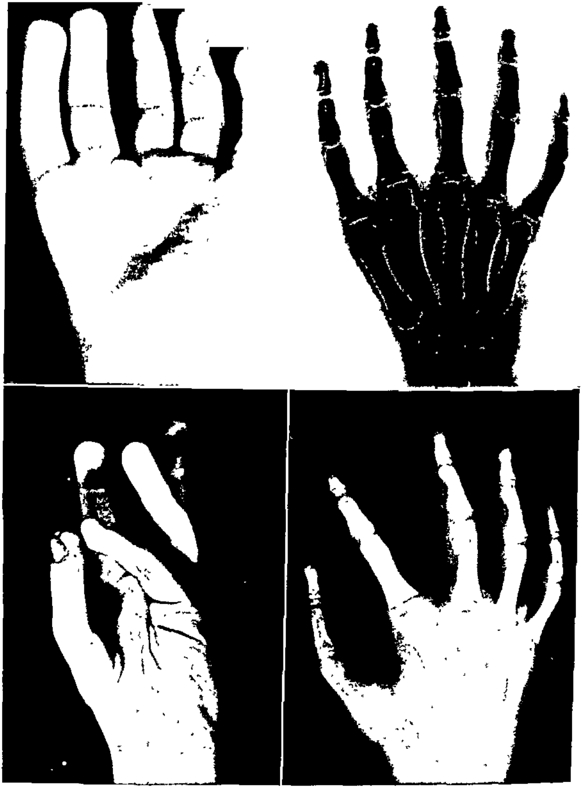


FIG 6 The "five-fingered hand" (*Top, left*) Palmar view of the left hand. (*Top, right*) Roentgenogram shows thumb replaced by a triphalangeal digit, and this entire ray cannot oppose. (*Bottom, left*) Postoperative result, opposing thumb and little finger. (*Bottom, right*) Postoperative roentgenogram. The Kirschner wires are still *in situ* (Fig 7 shows the operative technic.)

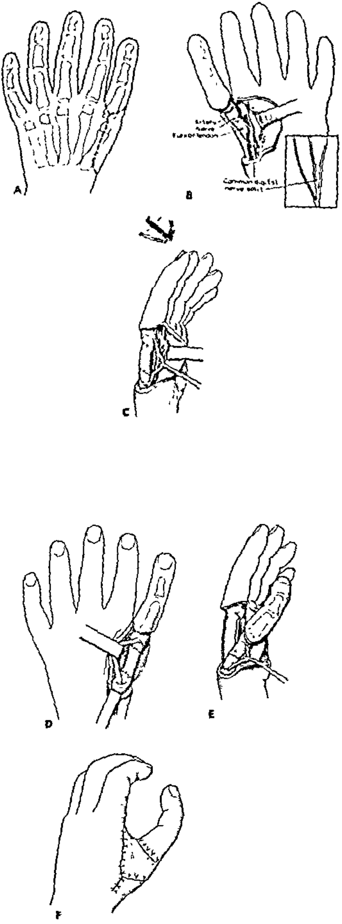


FIG. 7. Transplantation of the radial digit on a neurovascular pedicle to serve as a thumb (following the method of Bunnell and Littler). The method described here is a one-stage procedure.

(A) The incision (dorsal view). A circumferential incision is made around the base of the radial digit. This is continued proximally on the dorsum along the metacarpal almost to its base and then curves around the radial border of the hand onto the palmar surface. (B) Palmar view. The flap has been dissected and reflected, exposing the nerves and vascular supply to the radial digit and to the radial side of the adjoining finger. The common digital nerve is split proximally, while the branch of the digital artery to the radial side of the adjoining finger is cut and ligated. This provides arteries on both sides of the finger to be migrated. (C) The flexor and the extensor tendons are retracted. The dotted lines indicate the direction of the bone incision; the stippled area shows the portion to be excised. The angulation must be planned carefully. (D) Dorsal view. Most of the metacarpal is ablated. (E) The digit is rotated on its neurovascular pedicle into the position of opposition, and the metacarpal is pinned with Kirschner wires. The tendons are not shortened, but the muscle bellies accommodate themselves. (F) The closure. If difficulty is encountered in the closure, a free skin graft may be utilized to supplement the flap.

(Barsky, A. J.: Congenital Anomalies of the Hand and Their Surgical Treatment, Springfield, Ill., Thomas)

the thumb is absent and the index finger is present.

ECTRODACTYLIA

Ectrodactylia may be defined as the congenital absence of one or more digits. When part of a finger is missing, such as a phalanx or a metacarpal, the term *partial ectrodactylia* is applied.

Ectrodactylia may involve the thumb alone and may take a variety of forms. The mildest type would be the absence of part or

all of the digital phalanx (Fig. 8). When this particular form occurs, it requires no treatment. However, the cleft between the thumb and the index finger may be deepened by a Z-plasty, and this may improve the appearance of the hand.

When both phalanges of the thumb are absent and only the metacarpal is present, the function of the hand can be improved by deepening the web and thus increasing the abduction. In an otherwise normal hand, building up a post on the thumb to lengthen it should not be done as a routine procedure, for it must be remembered that a post—a skin tube with a bone graft—will never have the normal finger sensation that is so necessary for proper function.

From time to time one will encounter a case in which the entire thumb ray appears to be missing, yet some sort of stump can be palpated. Such a case is illustrated in Figure 9. On examining a very young infant with this condition, one should be most cautious in interpreting the roentgenogram, which may not show the presence of a metacarpal, although careful clinical examination will indicate its presence. Actually, the metacarpal is in a cartilaginous state, hence is not well visualized roentgenographically. As the child grows older, the presence of the parts can be demonstrated, as shown in Figure 9, *bottom, right.* In the case illustrated, a useful thumb stump was salvaged, and a hand was obtained that is capable of surprisingly good function.

Absence of the entire thumb ray is not uncommon, and the function of such a hand can be improved markedly by migrating the radial digit on a neurovascular pedicle, as shown in Figure 7, and performing a rotary

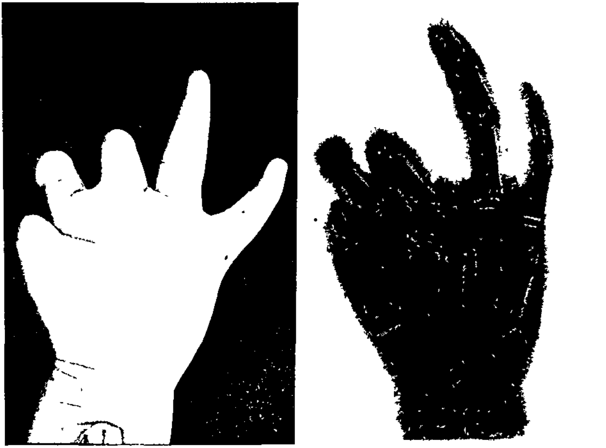


FIG 8 A case of partial ectrodactylia of the thumb. The 2 adjacent fingers are also affected. (*Left*) Palmar view. (*Right*) Only the proximal phalanx is present in the thumb and the index finger. In the middle finger, a rudimentary middle phalanx is present The thumb in this type of case, since it is movable and possesses good sensation, requires no treatment and should not be lengthened, for this would affect its sensation.

osteotomy on the metacarpal, shortening the metacarpal as well and placing the digit in the position of opposition. The author believes that this procedure is preferable to toe transplantation.

An unusual type of ectrosyndactylia is

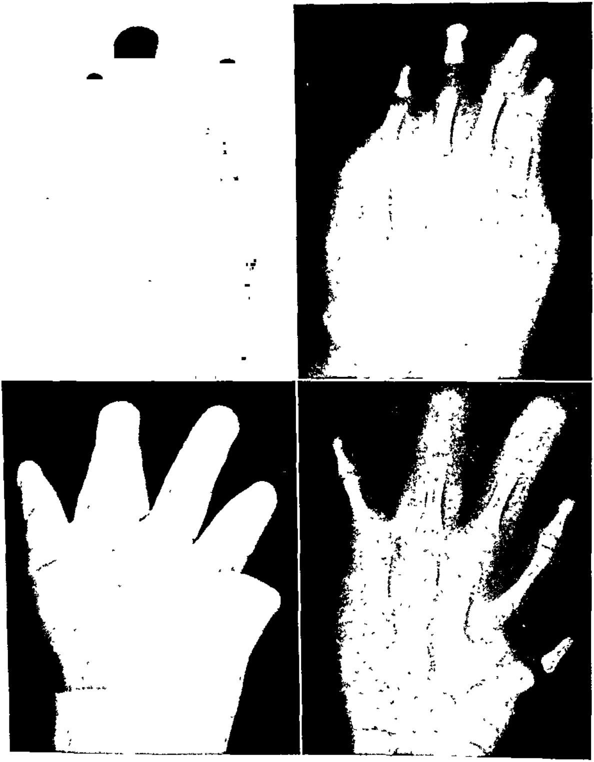


FIG. 9. A case of partial ectrosyndactylia of the thumb. (*Top, left*) Palmar view. A case of this type requires most careful study and surgical planning. (*Top, right*) Although not apparent on the roentgenogram, cartilaginous structures were present in the metacarpal region of the thumb and the index and the middle fingers. (*Bottom, left*) The fingers were separated, and a movable thumb stump was obtained. Tendon graft and transfer were required only to provide flexion for the index finger. All the digits move at the metacarpophalangeal joint. (*Bottom, right*) Roentgenogram taken 9 years after that at *top, right*.

shown in Figure 10. Here there is syndactylia of the thumb and the index finger. The thumb consists of two phalanges and a metacarpal, and the middle and the ring fingers show partial ectrodactylia. This might be considered a type of cleft hand. Figure 10, *right*, shows the result obtained by separating the thumb and the index finger.

Another variety of ectrosyndactylia involving the thumb is shown in Figure 11. This case illustrated an important clinical point. The preoperative roentgenogram (Fig. 11, *top, right*) is confusing and difficult to interpret, since there is overlapping and clumping of the distal phalanges. The first step in the treatment of such a case is to separate the thumb from the adjacent digit, utilizing a generous free skin graft. Subsequent roentgenograms then can demonstrate the relations of the bony structures without confusion (Fig. 11, *bottom, left*).

Still another type of ectrodactylia of the thumb, the *pouce flottant* (floating thumb), is encountered (Fig. 12, *top, left*). This term is descriptive, for the thumb literally floats, the metacarpal being totally or almost entirely absent, without a metacarpal joint, and in addition the thumb is attached on the radial side of the hand far more distally than the normal position of the thumb (Fig 12, *top, right*). In these cases the author has been repositioning the thumb on a neurovascular pedicle and migrating it to the thenar eminence. At a subsequent stage, a free transplantation of a metatarsophalangeal joint is done and, later, tendon transfers to the thumb in order to provide flexion and extension. Thus far the results in this procedure have been encouraging. However, it is too early to state conclusively that continued growth and development will take place (Fig. 12, *bottom, left and right*).

HYPODACTYLIA

Figure 13 shows a condition called hypodactylia of the thumb. Several varieties are found in which muscular action may or may not be present, but in either event the thumb

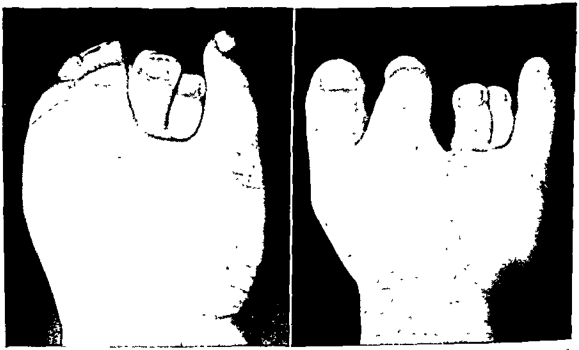


FIG 10 An unusual case of ectrosyndactylia. (*Left*) Dorsal view of the right hand. The thumb and the index finger are joined The middle and the ring fingers are rudimentary, they have no metacarpals or muscular attachments. The fifth digit is the only one that functions normally. (*Right*) Postoperative view after separating the thumb and the index finger.

FIG. 11. A case of ectrosyndactylia. (*Top, left*) Dorsal view of the right hand, showing pawlike appearance. Only 3 fingernails are present. (*Top, right*) Preoperative roentgenogram. In cases of this kind, visualization or orientation of the distal phalanges is difficult because of their overlapping. Only 3 metacarpals are present: thumb and index and little fingers. The little finger has 2 phalanges; the middle and the ring fingers each have 2 unsupported phalanges. It is difficult to evaluate the condition of the distal phalanges; therefore, the utmost care is required at operation, and the first step would be the separation of the thumb and the index finger. (*Bottom, left*) Roentgenogram after separation of the thumb and the index finger. It is now evident that the thumb has proximal and distal phalanges, the index finger a proximal phalanx; but the distal phalanx is fused with the adjacent distal phalanx of the adjacent rudimentary middle finger. (*Bottom, right*) After a second-stage operation, the child now has 3 usable digits: thumb and index and little fingers.

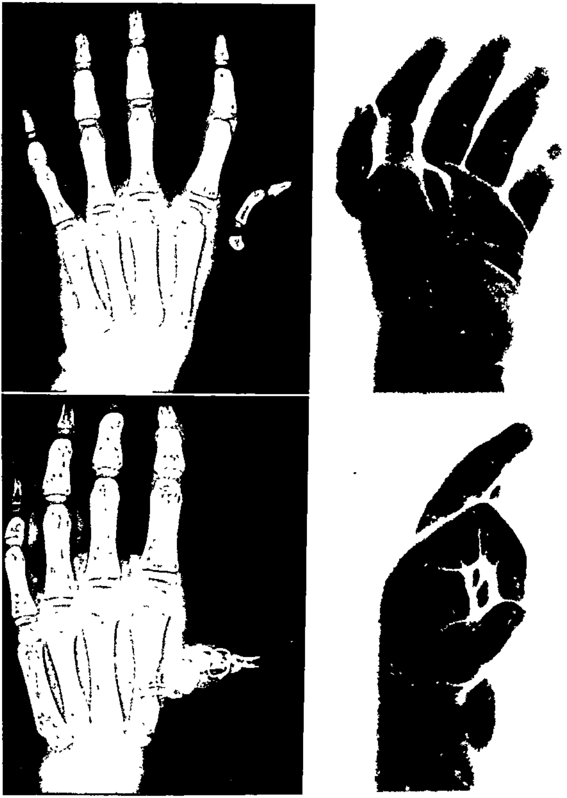


Fig 12. The floating thumb, a form of partial ectrodactylia. (*Top, left*) Roentgenogram. The thumb literally floats, since it has no metacarpal to support it. (*Top, right*) Its location is too far distalward, being attached at the level of the metacarpophalangeal joint rather than at the thenar eminence. The thumb has no voluntary movement but does have good sensation. At the first operation the thumb was transplanted to the thenar eminence on a neurovascular pedicle, thus preserving both vascular and nerve supply. (*Bottom, left*) Roentgenogram taken after the second operation, in which a free transplant of a metatarsophalangeal joint was carried out. Growth has continued thus far (3 years). (*Bottom, right*) The child pinching after tendon transplantation for flexion and extension.

is malpositioned and cannot oppose. In this case of hypodactylia there is a rudimentary thumb that contains two phalanges and a metacarpal. The thumb is totally deficient in muscular attachments and cannot be placed passively in opposition.

Treatment

In this particular type of case, if normal sensation is present and the joints are not flail but can be flexed and extended passively, one is justified in placing the thumb ray in a position of opposition, utilizing a flap to restore the cleft if necessary and later performing tendon transfers for flexion and extension. On the other hand, a thumb of this type devoid of sensation should not be reconstructed.

ABSENCE OF THE THUMB EXTENSOR

Congenital absence of the long extensor of the thumb is a rare anomaly. Function can be improved by tendon transfer with a free tendon graft. Although the excursion of either of the extensor carpi radialis muscles is not equivalent to that of a long thumb extensor, they may be used.

ANNULAR GROOVES

Annular grooves occasionally affect the thumb, although less frequently than the other fingers (Fig. 14). The grooves vary in extent and seriousness from a shallow groove slightly more than a skin crease to a very deep groove extending almost down to the bone.

At one time these were regarded as "amniotic" grooves, or sometimes they were called "uterine amputations." However, Inglis,[10] who has contributed much to the subject, has advanced the hypothesis that many examples of these constricting bands are not the result of disturbances of innervation, defective hormonal control, or extrinsic factors, but are due to "local inferiority of tissue in various parts of the body resulting from influences transmitted in the germ plasm and determined by fundamental biologic laws of growth and development."

Fig. 13. A case of hypodactylia with nonopposable thumb and no muscular control. The joints can be flexed passively, and good sensation is present. It is worth placing the thumb ray in a position of opposition by transplanting it on a neurovascular pedicle and later adding tendon transfers.

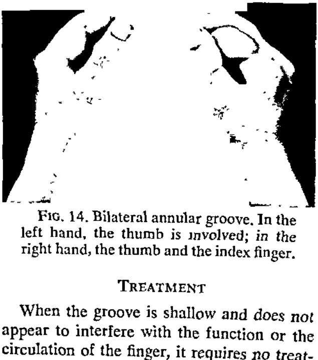


Fig. 14. Bilateral annular groove. In the left hand, the thumb is involved; in the right hand, the thumb and the index finger.

Treatment

When the groove is shallow and does not appear to interfere with the function or the circulation of the finger, it requires no treatment. However, deep or multiple rings may interfere with the circulation, and they should be operated upon.

FIG. 15. Macrodactylia of the thumb and the index finger. This should not be confused with the enlargement caused by either neurofibroma or hemangioma.

After excision of the grooves down to the normal structures, the subcutaneous tissues should be approximated carefully, and Z-plasties may be done. A word of warning is in order. A groove entirely circling the finger should be dealt with in two stages, half the finger at each stage. It is possible to excise completely the constricting band around the finger, but, unless extreme care is exercised, the circulation of the distal portion of the finger is endangered. When the fingertip beyond the constriction has no sensation and is flail, it should be ablated.

MACRODACTYLIA

The index and the middle fingers are involved most frequently in macrodactylia. Macrodactylia of the thumb is comparatively rare. (Fig. 15). True macrodactylia is referred to here, not that caused by neurofibroma or hemangioma.

TREATMENT

Not much can be done in the treatment of this condition except partial amputation to shorten the thumb. In doing this, one would excise the interphalangeal joint and arthrodese the shortened digit, preserving the nail and the tip of the finger.

ACHROCEPHALOSYNDACTYLIA

In this condition the thumb has a characteristic appearance, as shown in Figure 16. The two phalanges are fused and deviated radially.

TREATMENT

No treatment is indicated for this deviation, but in a selected case it is possible to arthrodese the joints if it seems that the function of the thumb could be improved.

The great toe takes on a similar appearance. However, the deviation may be so marked as to interfere with wearing a shoe. In the case of a toe, ablation or repositioning by an osteotomy of the metacarpal may

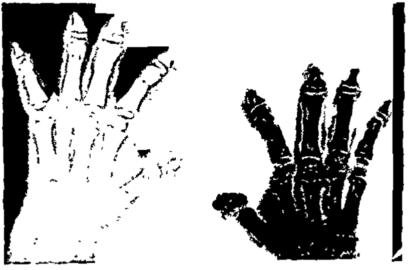


FIG. 16. Achrocephalosyndactylia. The 2 phalanges of the thumb are fused, and there is a marked radial deviation of the phalangeal portion of the thumb Note that there are only 2 phalanges in the remaining digits. The toes are affected similarly.

be performed. A flap from the lateral side of the great toe, transplanted to the medial side to make up the deficiency of coverage of the concave surface, should be an added procedure.

ARTHROGRYPOSIS

This curious condition, characterized by articular rigidity, occasionally affects the thumb (Fig. 17). A recessive hereditary factor has been reported; the author has found a familial tendency in his own patients.

Gilmour[9] has found in arthrogryposis absence of the extensor pollicis longus, the extensor indicis proprius and the extensor pollicis brevis muscles. This absence, counter-balanced by a normal flexor muscle of the thumb, would account for the position of the thumb.

Middleton,[16] who has studied the condition in lambs, found in the human being replacement of the extensor pollicis longus by remnants of muscle fibers in adipose tissue and fibrous strands. Weak electrical response was elicited occasionally, but there was no reaction of degeneration.

The author found a bilateral thumb contracture in a 5-pound stillborn fetus and had the opportunity of performing an autopsy. There was absence of the extensor pollicis brevis, with the extensor pollicis longus ending in a fibrous band at the base of the proximal phalanx of the thumb. The thumb metacarpophalangeal joint was fixed in flexion subluxation, with the base of the proximal phalanx displaced toward the palm. The thumb interphalangeal joint was fixed in flexion.

There has been some discussion as to whether or not the stiffness in the joints in the living subject is the primary cause of limitation of motion. The author has found no evidence of inflammatory joint changes, and one might conclude that joint fixity could be caused by disuse. Lack of motion in such a condition might cause the peri-

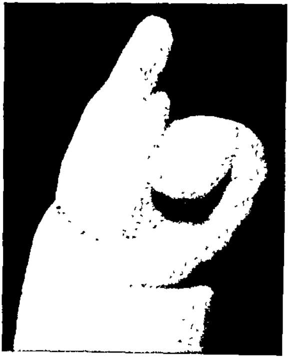


FIG. 17. Arthrogryposis of the thumb, together with absence of the index, the middle and the ring fingers. This is really a case of ectrodactylia complicated by arthrogryposis.

articular tissue and the skin as well to become contracted.

TREATMENT

Treatment in these cases is difficult, and the prognosis is not very hopeful. Very early treatment by splinting in the proper position may result in improvement if enough normal muscle fibers remain to function. However, splinting of the thumb in a very tiny infant is a most difficult procedure.

SUMMARY

The thumb, the most important digit of the hand, is affected frequently in congenital anomalies. Various congenital malformations of the thumb have been considered. Some of these, such as polydactylia and syndactylia, occur frequently and are found both as a single anomaly and in combination. Other malformations of the thumb are less common. The triphalangeal nonopposable thumb and a one-stage operative repair have been described. Ectrodactylia, mani-

festing itself in various degrees of severity, has been discussed, and hypodactylia of the thumb as well. Still other conditions, such as annular groove, macrodactylia and arthrogryposis, have also been discussed. In *each instance, the method of surgical correction* found to be most useful by the author has been presented.

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Anomalias Congenite del Pollice

Summario in Interlingua

Le pollice, le plus importante digito del mano, es frequentemente afficite in anomalias congenite. Varie malformationes congenite del pollice es discutite. Certes de istos —per exemplo polydactylia e syndactylia— occurre frequentemente, tanto in isolation como etiam in combination. Altere malformationes del pollice es minus commun. Es describite le pollice a tres phalanges que non pote opponer se al altere digitos. Le reparo de iste condition per un intervention chirurgic a phase unic es etiam describite. Ectrodactylia es discutite in su manifestation con varie grados de severitate. Etiam le phenomeno de hypodactylia del pollice es discutite. Le mesmo vale pro sulcos anular, macrodactylia, e arthrogryposis. Pro omne le conditiones mentionate, le methodo de correction chirurgic es presentate le qual se ha provate le plus utile in le experientia del autor.

11

The Care and the Treatment of the Burned Hand

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AND

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The established principles of surgical management of burns apply to the hand as well as to any other area, but the burned hand presents special problems because of certain anatomic and functional features. Effective hand function is necessary for livelihood and for performance of many daily tasks. Even slight impairment of mobility or sensation may result in a significant loss of usefulness. The exposed hands are more liable to trauma than is any other part of the body. In addition, important structures, tendons, vessels, bones, joints and nerves lie close beneath the protecting skin and subcutaneous tissue. Apparently insignificant trauma may produce severely disabling injury to these structures.

In the extensively burned patients precedence must be given to general care: restoration and maintenance of circulating blood volume, effective respiratory exchange and avoidance of surface contamination. Unfortunately, these vital considerations may divert attention from the burned hand. By prompt, carefully planned care of the injured hand, late crippling deformities may be avoided or at least minimized. The purpose of this review is to enumerate some of the principles of treatment that have proven to be effective in ensuring the best possible salvage of the burned hand.

ETIOLOGY AND TYPES

Two principal types of thermal burns of the hand should be recognized:

First, the exposure type, usually from exposure to flame or intense heat. The portion involved most commonly is the dorsum of the fingers and the hand, usually the result of efforts to protect the face or other parts of the body or of attempts to smother the fire or to escape the heat. The hand often is flexed, so that the palmar surfaces are less seriously injured than the dorsal. It is common for both hands to be burned. Often in burns involving the dorsum of the hand, there are burns elsewhere, as, for example, the face, the forearm and other exposed parts.

Second, the contact burn from direct exposure to hot objects. Frequently these burns involve the palmar surface of the hand; for example, the child or the baby who falls against a hot stove or the worker in industry who touches a hot surface such as rollers or mangles. Usually, the burns are discrete, involving only one hand or a portion of one hand. Other causes of such localized burns may be spilled hot liquids or

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spatterings of molten metal, or direct friction. Although these localized burns are associated only rarely with other burns, injuries to other structures such as bone (fractures), tendon (lacerations) and crushing are not uncommon.

EVALUATION OF DEPTH AND EXTENT OF BURN

An estimate of the depth and the extent of the burn is essential. Usually, the appearance of the local wound is the most accurate way of determining the depth, but the mode of burning may provide valuable information. For example, brief exposure to hot liquids or momentary exposure to a flash of intense heat may produce only second-degree damage, while prolonged exposure to steam or flame usually produces a third-degree burn. The significant local findings of color, moisture and sensation are shown in the following table:

	2ND DEGREE	3RD DEGREE
Color	Red or pink but blanches with pressure	Usually blanched pearly white or charred
Sensation ..	Present and usually quite painful	Anesthetic
Moisture ..	Blistered or weeping	Dry or charred

Other methods include radioactive tracers and intravenous dyes, which are helpful in estimating the depth of a burn but require special equipment for the determinations.

Some authors subdivide the second-degree burn into two groups: (1) the superficial second-degree burn; and (2) the deep second-degree burn. In the former, an abundance of epithelial tissue in the form of sebaceous glands and hair follicles remains in the deeper layer of the dermis, and from these healing will take place spontaneously. In the so-called deep second-degree burn, there is an *almost* complete destruction of the skin; nevertheless, islands of epithelial tissue remain, and from these some spontaneous healing can develop. However, the character of the healing that arises from these tissues is of such poor quality that it has seemed to the present authors to be wiser to classify these as third-degree burns. If they are dealt with as third-degree burns, the final functional and esthetic result will be far superior to that resulting from prolonged but spontaneous healing. Only if the patient's general condition is precarious, should these areas be treated as if they were second-degree burns.

It may be difficult to estimate the depth of the palmar burn because of the thickness of the skin of the palm. Seldom should one consider excision of this highly specialized, irreplaceable tissue unless the damage is very obviously deep or until more accurate evaluation can be made at the time of the first change of dressing.

PRIMARY LOCAL TREATMENT

The initial objective of local treatment should be prevention of further bacterial contamination, either from those in attendance or from debris on the skin. Thus, in the first-aid management, a clean protective covering for the hand should be applied. Gentle cleansing of the surface is desirable if the hand has been exposed to significant contamination or unnecessary handling. The decision as to whether to apply a dressing at once or to do a preliminary washing and débridement of loose tissue from the surface must be made by the attending surgeon. However, it should be stressed that general anesthesia seldom will be required for any primary local treatment and that nothing is gained by rupture of blebs or débridement of the attached covering that remains as a most effective barrier against bacterial invasion.

DRESSINGS

Despite the enthusiasm for the "exposure treatment" of burns, it is generally agreed that the deeply burned hand should not be "exposed." The most important rea-

son is that the "position of function or rest" of the hand must be maintained. This cannot be done effectively without wrapping the hand so that it is held in the correct position on a supporting splint. A Mason Universal Splint is useful for this purpose, or, if unavailable, a mound of sponges on a flat splint may be utilized. The wrist should be extended partially; the interphalangeal and the metacarpophalangeal joints should be flexed partially; the thumb should be rotated toward the palm in a position of opposition. The stabilizing collateral ligaments of the finger joints are tense only in the flexed position. When the fingers are extended, they are relaxed but will tighten rapidly if the swollen fingers are left in the extended position.

A single layer of fine gauze, either dry or lightly impregnated with petrolatum or other ointment, is most useful against the skin. This dressing can be removed with less trauma to the injured tissues and, consequently, less pain to the patient than a coarser gauze. Yet there is a free escape of exudate from the burned surface, so that pooling of serum beneath an impervious dressing does not occur. The initial layer of gauze in turn is covered by a bulky dressing wrapped firmly in place. The term *pressure dressing* has been avoided for two reasons: (1) because in the hand, at least, minimal reduction in local fluid loss can be expected by the application of pressure because the fluid is carried rapidly up this arm in the lymphatics; and (2) if the dressing is applied properly, with gauze separating each of the fingers and thumb, a tight pressure dressing may pose a very real danger of ischemia to the digits and/or unnecessary discomfort to the patient.

Usually, the primary dressing is left untouched for 5 to 7 days. If, in the first evaluation, no deep (third-degree) burn was present, little is gained by this early removal of the dressing, but the patient may be more comfortable and early active motion may be begun if the outer layers of gauze are discarded. Inspection of the burned area is desirable if there is any suspicion of a deep burn. Early surgical excision or débridement of the destroyed tissue and prompt wound closure with skin grafts should reduce the period of immobilization, avoid local infection and decrease fibrosis. The lines of demarcation between viable and nonviable tissue are usually clear by 5 to 7 days, much more obvious than immediately after the injury. However, when faced with a distinct, localized, deep burn with minimal systemic derangement, the surgeon should consider immediate excision and skin-grafting in preference to the delays proposed above. Some writers find that soaking the burned hand by immersion in a saline or a weak hypochloritic solution is useful in hastening spontaneous separation of the slough. It also permits some active motion of the hand. If contamination and maceration can be minimized, this may be an effective method of débridement and mild physical therapy, but at the same time it is difficult to carry out. In general, the drier the hand can be kept, the less likelihood there is of sepsis unless exudate dries as a crust on the surface and acts as a barrier to the escape of serum. Prompt débridement of this obviously deeply burned tissue will eliminate possible foci of infection, and immediate or delayed (2-5 days) skin-grafting will hasten the convalescence. However, in the extensive burn involving the dorsum of the hand and the fingers, there may be difficulty in making a correct primary diagnosis. Since these patients often are burned elsewhere, the decision can reasonably be postponed for a few days until the general condition of the patient permits a surgical procedure. By this time the line of demarcation between deep burn and superficial burn usually is apparent. The procedure should be done in an operating room fully prepared for débridement and skin-grafting. If there is doubt that the patient can tolerate the procedure, longer

delay before exposing the hands to the hazards of unnecessary contamination is reasonable. In the healthy patient, delays as long as 10 days before débridement and grafting usually are well tolerated.

If the lines of demarcation are not obvious or if the burn involves tendon or bone, it may be desirable to be quite conservative and to inaugurate a program of daily dressings after the first dressing change, débriding only that tissue which has undergone spontaneous separation. In deep burns it may be the third week before the full extent of muscle, tendon or bone loss can be determined. Not infrequently the outer layer of the bone or the tendon will separate, and the deeper layers will prove viable and will provide the necessary continuity of structure that might be completely destroyed in the too enthusiastic débridement. The granulation that develops can be closed promptly with skin grafts up to the devitalized bone or tendon. By this technic there may be some conservation of tissue, for a spontaneous line of demarcation of bone or tendon is more likely to be accurate than an arbitrary surgical excision. With meticulous care spontaneous healing will occur frequently over the exposed but still viable bone or tendon.

SPECIAL TYPES OF BURNS

Electrical burns are characterized by extreme depth and widespread horizontal extension of the destruction. This is due to the effort by the current to find the path of least resistance, which usually is along blood vessels or through muscles. The skin and the bones offer considerably more resistance than these other tissues; consequently, it may be difficult to determine the extent or the depth of the burn on initial examination. Spontaneous débridement may be prolonged because of the wide spread of the necrosis subcutaneously Operative débridement of the areas of electrical burn is being urged more and more in surgical writings. The morbidity and the crippling that occur with the slow sequestration of necrotic tissues are urgent reasons for removing them. Of necessity, the débridement must be widespread to encompass the damaged area. Repair may require a more complex direct flap rather than a free skin graft.

Chemical burns usually are classified with the contact burns with hot objects The problems in these two types of burns are essentially the same. In addition, it is important to flood the hand thoroughly with water before a dressing is applied.

CHEMICAL DÉBRIDEMENT

Despite the enthusiasm for chemical débriding agents by some authors and in the advertisements, there is little evidence that any collagenase or other application for removal of necrotic burned skin has been found. Reports of studies as controlled as is possible are unconvincing, because equally rapid separation can be achieved by meticulous care of the wound itself. The failure of chemical débriding agents is a compelling reason for surgical débridement when at all possible.

ANTIBACTERIAL AGENTS

Massive antibiotic therapy is desirable in all severe burns of the hands. Cultures, both aerobic and anaerobic, from the skin at the time of initial examination will be helpful often in deciding which agent to combine with the ubiquitous penicillin. Treatment is continued as long as there is any risk of invasive infections. The dangers of sensitivity to the drug and the possibilities of resistant organisms should alert the surgeon to the desirability of periodic omission of antibiotic therapy. There is no evidence that topical antibiotics are of value in the initial care of the burned hand. Antitetanus therapy—a booster dose of tetanus toxoid or a large dose of tetanus antitoxin—is desirable

SKIN-GRAFTING

Preparation of raw surface for a skin graft demands daily or twice-daily changes of dressing, careful removal of exudate and

slough, and reapplication of a firm fitted and moist gauze dressing. Bacteriologic cultures usually grow a wide variety of organisms on the surface. If they are abundant, or if *Bacterium pyocyaneum* is present, the wound assuredly needs further care before grafting can be contemplated. Delay of a few days is preferable to a catastrophic loss of skin grafts. Perhaps the best clues as to the readiness of the wound to accept a graft are: minimal exudate; the appearance of the granulation, which should be firm and bright red; and the visible evidence of a marginal spread of epithelium.

The excision of granulation tissue is seldom necessary in the early days after the separation of slough. The connective tissue beneath the granulating surface develops slowly. If the raw surface has been present for many weeks, the connective-tissue layer thickens and constricts the blood vessels, which must penetrate it to nourish the skin graft. Thus, shaving off the granulation and underlying scar tissues may be desirable at the time of grafting the chronic ulceration of an old burn.

Split skin grafts may be secured in a number of ways, including the freehand method with a long slender skin-graft knife, or the mechanical methods with a variety of dermatomes, including the Padgett, the Reese and the Brown types. Despite the calibrations of the graft-cutting machines, each surgeon will handle the instrument differently and, consequently, cut grafts of different thickness These differences and the differences in skin thickness introduce risks of permanent damage to the donor site, because too thin a layer of dermis is left from which normal healing must arise. Unless the roots of hair follicles and sebaceous and sweat glands remain, a raw, infected, painful wound will result. Consequently, care must be taken not to cut the graft excessively thick.

Almost without exception raw surfaces of the hand should be closed with split skin grafts This is true following surgical débridement, as well as on a granulating wound. The normal shrinkage of a free graft varies with the thickness of the graft—the thicker the graft the less the shrinkage. If the healed graft is kept under some tension, shrinkage can be minimized. Thus, on the dorsum of the hand, the primary split graft usually will suffice because of the action of the powerful flexor muscles. On the other hand, palmar contracture may develop despite prompt closure of the open wound with thick split grafts. The definitive release of palmar contractures frequently requires covering with full-thickness free grafts.

Only rarely is a pedicled flap indicated early in the treatment of the burned hand. Occasionally, exposed tendons, joints or bones may be salvaged if they are covered promptly by a blood-bearing flap. Nice surgical judgment is called for in making these decisions. The leaving of necrotic tissue or an infected joint beneath a flap can jeopardize the result and may lead to serious complications in the uninfected donor area. A more prudent course is to postpone any definitive procedures until complete healing has been achieved with free skin grafts.

Exposed tendons, bones or open joints of the fingers may interfere with or prevent the formation of a completely acceptable granulating surface despite meticulous efforts to prepare the surface for grafting. By open grafting technics, delays in closing the wound with skin can be minimized. The prompt spontaneous and firm adhesions that develop between a split skin graft and a granulating surface are well recognized. By taking advantage of this adhesion the surgeon can leave the graft exposed to the air and even allow minimal motion if this is desirable. The graft is measurably cooler and drier than if covered by a dressing and, consequently, less liable to autolysis or destruction by sepsis. It must be emphasized that this method has only limited application. There is still no better method for the protection of a graft on a well-prepared surface than an accurately applied dressing. Only when there are technical problems of effec-

tive immobilization of the graft or the condition of the granulating wound is uncertain will the open-grafting technic offer an alternative method that may prove to be simpler, more effective and less hazardous in securing closure.

PROGNOSIS

Obviously the prognosis depends to a major degree on the extent of the anatomic damage. The damage to injured but not necrotic tissues can be increased if severe sepsis is allowed to develop. This is the compelling reason for early débridement of all necrotic tissue. Functional recovery of the hand can be retarded, even permanently impaired, if there are delays in securing wound closure requiring prolonged immobilization because of sepsis, pain or slow healing. Deep fibrosis is increased by the persistence of granulating areas. There must be alterations in the lymph flow with localized lymphangitis and obstruction, the evidence of which is the chronic edema that subsides rapidly after the hand is healed.

Final functional recovery of the severely burned hand is usually slow, calling for great patience by the individual and his surgeon. Active exercises are far more beneficial than any energetic passive manipulation. Soaking the hand in warm soapy water and lubrication with a bland ointment will help to limber stiff joints and soften inelastic skin grafts. Often one is surprised at how much recovery will occur spontaneously in a well-motivated patient if the surgeon is not tempted to undertake premature operative procedures.

Further surgical procedures may be indicated. These include the resurfacing of important areas with flaps for greater mobility or as a precursor of surgery on deeper structures, capsulotomy of metacarpophalangeal joints, tendon transplants and repair of contractures with skin grafts. In choosing the procedure the surgeon should select the one that will accomplish the desired result most rapidly and effectively so that the period of immobility of the hand will be as brief as possible.

SUMMARY

Burns of the hand can produce severely crippling disabilities. Early excision of all necrotic tissue permits primary closure of the wound with skin grafts and earlier functional recovery. Burned tendon and bone should be treated more conservatively than skin, because evaluation of the degree of damage is less certain. Partial salvage of these tissues by waiting for spontaneous separation may obviate complicated reparative procedures at a later date. Even after healing of the hand is complete, functional recovery is slow, requiring extreme patience by the individual and restraint by the surgeon. Much of the ultimate recovery depends on the motivation of the patient himself.

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Cura e Tractamento del Mano Ardite

Summario in Interlingua

Le establite principios del tractamento chirurgic de arditura in general es applicabile etiam a arditura del mano, sed le mano ardite presenta problemas special a causa de certe factores anatomic e functional. In casos de arditura de grado sever, le prime

consideration debe esser dedicate al tractamento general, sed un cautemente planate programma pro le mano ardite es frequentemente capace a evitar subsequente deformitates invalidante. Un del plus difficile problemas in arditutas afficiente le mano es le evaluation del profundor e del extension del lesion. Tamen, si isto pote esser determinate accuratemente, le prompte excision de omne areas de histo necrotic pote resultar in le possibilitate de un clausion primari del vulnere per medio de graffos de pelle e consequentemente in le plus prompte restablimento functional. Del altere latere, si osso o tendines es ardite, un attitude multo plus conservatori deveni indicate pro evitar le excision de areas de histo que es possibilemente ancora viabile. Le salvation de osso e tendines pote obviar le necessitate de un complicate serie de procedimentos reparatori in tempores futur. Le restablimento final del severmente ardite mano depende de alte grados de patientia e de attention diligente del parte del chirurgo e de un forte motivation del parte del patiente mesme.

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Dupuytren's Contracture; a Guide for Management

L. D. HOWARD, JR., M.D.*

In the 127 years that have passed since Guillaume Dupuytren established the pathologic entity that bears his name, much has been written on such aspects of the disease as etiology, incidence, pathology and treatment. An excellent summary, with additional contributions, was published by Skoog[6] in 1948. Since then the subject has remained popular, as indicated by the number of publications, but little has been added to the sum of knowledge. Many of the articles emphasize a variety of operative technics.

PROBLEM

There is only one major problem in the surgical treatment of Dupuytren's contracture; i.e., the prevention of postoperative stiffness of the small finger joints or, should it occur, its treatment. The more technical aspects of the actual surgical procedure are significant, especially as they bear on the postoperative recovery. However, joint stiffness can occur irrespective of incision, hematoma or skin slough. Although these may be factors of some importance, they are not the cause of stiffening. For these reasons, the unseasoned surgeon may show enthusiasm for an operative form of treatment until he is confronted with his first dismal failure. The literature places little emphasis on the problem of stiffening, either as to cause or cure. Long-term follow-up reports concerned with later involvement in unoperated areas or recurrence at the operative site are few.

Dupuytren's contracture usually appears in middle and later life, and has a high incidence of bilateral involvement. It rarely if ever causes total incapacitation. Sex makes no difference in the evaluation of the case except from the standpoint of cosmetics. Generally, women prefer a finger that looks well and can take a glove to one that functions well.

The disability of Dupuytren's contracture is due to limited extension of the digits. Rarely is there lack of strong and complete flexion preoperatively unless there is an associated arthritis of the small finger joints The pathologic process involves the palmar and the digital fascia and, to a varying degree, the connective-tissue layer of the overlying skin. The process never involves the flexor tendons or the volar digital nerves or vessels.

In most cases of Dupuytren's contracture, other stigmata of arthritis or related collagen disorders are found on physical examination and from the history. Bursitis, early-morning stiffness of the fingers, transient numbness of the fingers, Heberden's nodes, ganglia, trigger finger, tenosynovitis and knuckle pads are common.

Dupuytren's contracture is practically asymptomatic so far as local pain or tenderness is concerned. The condition is subject to periods of quiescence and activity. During the latter phase pain can be mild. If the pa-

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tient complains of much pain, a search should be made for other causes.

HISTORY

For the protection of the surgeon, and for an honest evaluation of the results of treatment, a careful initial history and physical examination should be made. The follow-up postoperative examinations should include accurate determinations of function.

A family history should be obtained relative to the presence of the disease in other members, as well as to the presence or the absence of rheumatic afflictions.

A personal history should include information relative to joint or connective-tissue disease apart from the Dupuytren's contracture. The date of onset and location of the Dupuytren's involvement should be noted, along with a chronologic history of periods of rapid advance or quiescence. The physical examination is best recorded by freehand sketches on the chart showing the type and the location of involvement and graphically portraying the limitation of digital extension.

PHYSICAL EXAMINATION

Type of Involvement (*Figs. 1 & 2*)

1. The "nodule," often first to appear, usually in the palm at the base of the ring or the little finger, tumorlike, roundish and firm. When active, it may be slightly tender and show slight redness of overlying skin.

2. The "cord," linear thickening of palmar or digital fascia, tightens bowstring fashion on extension of the digits. It is not tender and is best outlined with finger in maximum extension.

3. The "pit" may be the first evidence, or it may appear later, or perhaps not at all. This represents involvement and contracture of fibrous-tissue strands from the palmar fascia to the dermis of the skin, creating dimpling.

4. The "poor skin," an area of absolute fixation of skin to involved fascia beneath, usually a nodule. Such skin is less thick than in uninvolved areas. If the extent is great, it will be subject to postoperative necrosis and, therefore, may need removal at

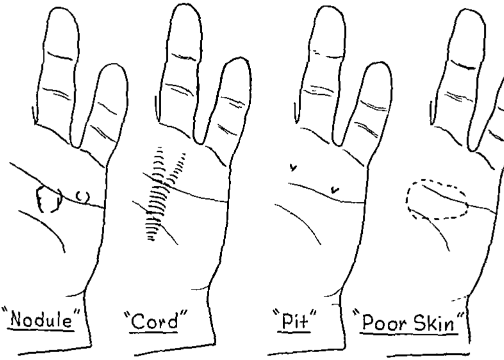

Fig 1. Clinical manifestations of fascial involvement in Dupuytren's contracture.

the time of surgery, followed, if necessary, by replacement with an immediate skin graft.

Limitations of Function

The limitation of extension of the fingers is best shown by a sketch indicating the distance of the fingertips from a straight line drawn in extension of the metacarpals (Fig. 3A). When the contracture is so severe as to make this measurement impractical, the limitation of extension is best recorded as the distance the tip of the finger clears the distal crease of the palm (Fig. 3C). Thumb-web contractures may be recorded by comparing the involved with the uninvolved thumb when both are extended. In case both thumb webs are affected, the amount of contracture can be recorded by measuring the distance that the pulp of the thumb spreads from the radial side of the index finger (Fig. 3B).

Postoperatively, the major concern will be the limitation of flexion of the fingers due to

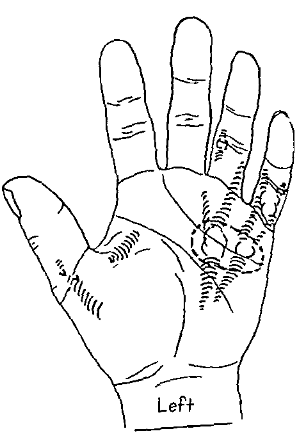

Fig. 2. A freehand sketch of a case of Dupuytren's contracture showing location and type of fascial involvement.

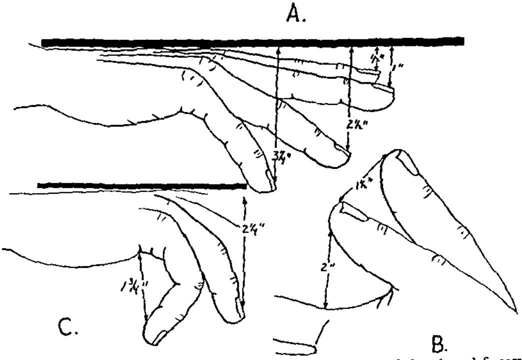

Fig. 3 Recording by sketch the limitation of extension of thumb and fingers (A) Mt ure from tip of finger to a rule held on dorsum of hand paralleling metacarpals and overhanging the digits. (B) Methods of recording by sketch, limitation of extension of the thumb. (C) In cases of severe contracture the clearance distance from the distal crease of the palm may be used instead of method depicted in A

stiffness of the small finger joints. This may be recorded graphically or by figures showing the distance the tips of the fingers fail to reach the distal crease in the palm on voluntary flexion (Fig. 4A). Limitation of flexion of the thumb is recorded by a flexion adduction measurement; for example, the amount by which the tip of the thumb fails to touch the distal palm at the base of the fifth finger (Fig. 4B). A detailed record may be made by measuring the angle of flexion of each individual joint and recording them in table form.

TREATMENT

Nonoperative or conservative treatment consists of doing nothing. Splinting may prevent an increase of the contracture, but in general splints are poorly tolerated. Once a contracture develops, an attempt to lessen it by splinting is unrealistic. No local or systemic medication or treatment by any physical modality has proven to be effective.

Indications for Nonoperative Treatment

1. An insufficient contracture, one that is not disabling in any way. Avoid the risk of stiffening the hand in the absence of an actual contracture.

2. Individuals with physical impairments that contraindicate surgery in other than emergency instances.

3. Individuals with evidence of severe advancing arthritis of the hands and showing already limited flexion of the fingers.

Operative Treatment

Before any surgery is performed, advise the patient of what you expect to do and warn him with regard to the possibility of postoperative stiffness of the fingers. Obtain

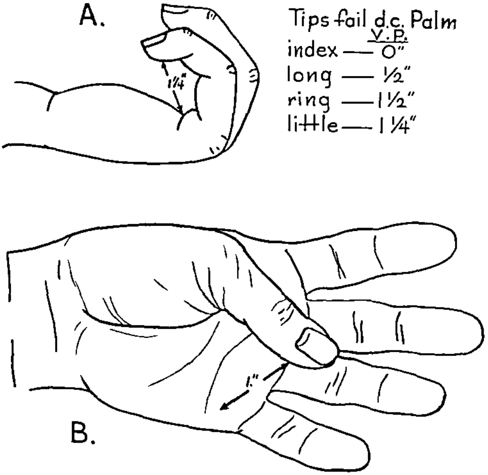

Fig. 4. Method of recording by sketch and table (A) the limitation of flexion of the fingers and (B) the thumb.

the co-operation of the patient by vesting in him some of the responsibility for the post-operative care. Unless there are extenuating circumstances in bilateral cases, operate on one hand at a time and on the one that is the more involved. This helps the patient to decide whether or not he wants surgery performed on the other hand after observing the results of the first.

Operative treatment is divided into three types, depending on the extent of the surgery:

Fasciotomy

This procedure is useful primarily in relieving flexion contracture of the proximal (metacarpophalangeal) joints. It is not recommended for the relief of flexion contracture of the middle (proximal interphalangeal) joints due to technical difficulty and risk of volar digital nerve damage.

Indications for Fasciotomy:

1. As a preliminary to fasciectomy in severe cases. The procedure allows the palmar skin to stretch out a bit before the major surgical undertaking.
2. For older, retired or nonworking individuals still physically active in sports or hobbies. The procedure is especially applicable in those cases with limited involvement in a quiescent stage.
3. For skilled workers who cannot afford the time off (minimum of two months) for more extensive surgery. (Explain need of later fasciectomy or repeat of fasciotomy.)
4. For patients who have a moderate degree of arthritis of the hands or for other reasons are prone to joint stiffness.
5. For individuals who because of other physical impairments can tolerate only minimal operative procedures.

How To Get the Most Out of the Fasciotomy:

1. So far as is mechanically possible, sever all fibers of the fascia in the contracting band so that a true gap is present in the line of fascia pull.
2. Since one digit can hold back another, *after the more severely contracted one is let* out check the adjacent digits for tightness of fascia and sever bands of these to make additional gain.
3. Avoid doing fasciotomy at the point at which the skin is the most involved. If the fascia is released under poor skin and the finger is stretched out, there is apt to be a traumatic rupture of the skin, thus producing an open wound. In such cases it is much *better to divide the fascia in two places,* one above and one below (Fig. 5). If a skin wound is created, it should be closed by suture. Often these wounds will close more readily from side to side in a longitudinal line than edge to edge in the transverse plane. In the event that the wound cannot be closed by suture, it should be covered by a small split-skin graft.

   It never pays to leave an open wound on *the hand even for a short period of time.*
4. Look for fascia involvement in the finger webs. This will prevent the extended fingers from spreading. A vertical approach in the web, with the fasciotomy knife, can release this band with much benefit. The same is true of contracting bands in the thumb web (Fig. 5).
5. Following fasciotomy the released fingers should be splinted intermittently in extension by means of a dorsal clock-spring type of splint. By use of such a splint, additional extension will be gained, as the uninvolved, but secondarily shortened, soft tissues stretch out.

Limited Resection of Involved Fascia

Indications for This Procedure:

1. Older individuals with localized involvement of long standing but without evidence of much progression.
2. Involvement within a digit, the palm being free or with very minimal involvement.
3. For patients whom you suspect will stiffen greatly after extensive surgery by reason of other physical signs or from experi-

ence following a previous operation on the other hand.

Radical or Complete Fasciectomy

Indications for Complete Fasciectomy:

1. Healthy individuals with widespread involvement and evidence of steady progression of the disease.

2. Young individuals who have local involvement that is progressive and give a family history of the disease with extensive involvement in other members.

How To Get the Most Out of Local or Complete Fascial Resection:

Operative Details:

1. Use standard proven incisions and technic. The McIndoe incisional approach is highly recommended (Fig. 6A & B).

2. Use sharp dissection as much as possible to avoid traumatizing the tissues by spreading scissor points.

3. Release the tourniquet before final closure and obtain as near complete hemostasis as possible. Elevate the hand to reduce venous bleeding.

4. Excise skin of questionable viability before closure and, if necessary, apply immediately a split-thickness or full-thickness skin graft. The best local source of a satisfactory full-thickness skin graft is an ellipse

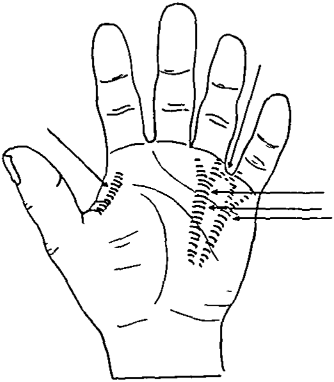

Fig. 5. Showing elective sites for fasciotomy. Note approach to digital and thumb web.

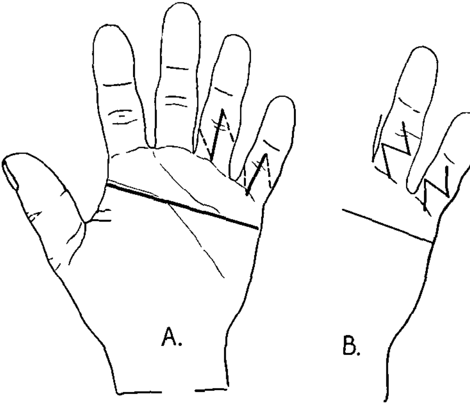

Fig. 6. (A) Surgical approach (McIndoe) to palm and digits for fascial resection. Broken lines on digits outline flaps for Z-plasty closure (B) Direct closure of palm and closure by Z-plasty for fingers.

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curs, the chances are great that flexion contracture will recur, even to a greater degree.

3. If, at the time of surgery, it appears that there is not a reasonable chance of adequate extension being obtained even by postoperative splinting, it is best to do an immediate arthrodesis of the middle finger joint in approximately 45° of flexion. By doing so, some shortening of the finger will result, and this in turn will relax the soft tissues that are under strain.

4. When a middle-finger joint has suffered long-standing and severe flexion contracture (90° or more), consider amputation as a method of treatment. This can be performed at the time of the surgery if the patient has been forewarned. In most cases the proximal finger segment can be saved, the dorsal skin of the distal two segments being utilized for volar cover. If the fifth finger has both its proximal and middle joints in severe flexion contracture with poor volar skin on the palm and the finger, amputation should be carried out through the distal end of the metacarpal. Then all the dorsal skin of the finger is available to cover any skin defect in the palm.

Thumb-Web Contractures. In severe thumb-web contracture, the involved area is best approached by incision in the line of the web, closing by Z-plasty type maneuver (Fig. 7A-C). If there is insufficient skin even for Z-plasty, the remaining denuded area can be covered with thick-split or full-thickness skin graft, with the thumb in the corrected position.

Persistent blanching of a finger on release of the tourniquet means arterial insufficiency. Relax the finger from the extended position and wait. If there is a Z-plasty on the finger, release and slide the points back to lessen the circumferential constriction. Prolonged arterial insufficiency means a poor finger, even though the digit survives. Advise the patient of the situation immediately after operation.

Associated knuckle pads had best be left alone. Excision frequently damages the central slip of the extensor tendon, leaving a boutonniere-type deformity.

A diffuse hard thickening of the palm after operation is a manifestation of the stiffening process. The tissues will soften in time with active use of the hand. Maximum improvement postoperatively may take many months.

CONCLUSION

A few salient points have been proposed in the management of Dupuytren's contracture. These are intended as guides, not as rules. A careful preoperative appraisal of

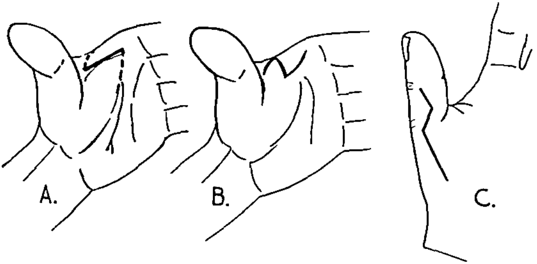

FIG. 7. (A) Incision used to approach thumb web for excision of involved fascia. (B) Closure by Z-plasty. (C) Suggested incision to use on radial side of thumb and thenar for fascial resection.

from the antecubital area. The defect thus created can be closed directly and without the undermining of skin edges by simply flexing the elbow. Two weeks of splinting will suffice.

5. Close the operative wounds loosely to allow drainage and thus avoid the need of a drain. Do not use impervious dressings on the wounds, as these seal the wounds almost as effectively as suture. Hydrocortisone flushed throughout the wound just prior to closure will help minimize postoperative reaction and pain.

6. Avoid a compression dressing, as the risk of a dressing that is too tight far outweighs the danger of hematoma.

7. Dress the operated hand with voluminous soft dressings in the position of function, with the wrist in slight dorsiflexion. Immobilize by use of plaster splints on the forearm and the hand.

Postoperative Care; the Minimum Essentials:

1. Elevate the operated extremity to heart level or above at all times. This is probably the most important controllable factor to help minimize swelling and stiffness.

2. Splint the operative wounds until healed.

3. Permit early motion of unoperated areas of the hand.

4. When all wounds are healed, occupational-type therapy is started. Avoid treatment that requires prolonged dependence of the hand. Avoid forcing the small finger joints passively.

5. If a flare of stiffening develops, cortisone can be given systemically for symptomatic relief, but this should be done under careful medical supervision.

Postoperative Complications:

1. Pain and swelling are danger signs. Release the dressing, maintain immobilization and elevate hand well above heart level.

2. Hematoma in the palm is dangerous because it promotes thrombosis of the skin flaps. If the hematoma is large, return the patient to surgery immediately and evacuate the clot. Then the wound can be resutured or, if a gap exists, closed with thick split-skin graft. If the hematoma is small and localized, it can be drained out with a needle or through a small opening in the wound after 8 to 10 days, at which time the blood will be fluid.

3. If necrosis of any part of the skin flaps occurs, excise the dead skin as soon as demarcated and cover the area with a split-skin graft. By so doing, surface infection is avoided and much time is saved.

4. Stiffening of the small finger joints may develop gradually, but usually it shows up on the tenth or the fourteenth day as a flare reaction, characterized by spontaneous joint pain, swelling and limited motions. During the acute phase, the condition should be treated by rest, constant elevation of the hand above heart level, and salicylates and/or cortisone. Never try to force swollen, painful joints, either voluntarily or passively, to gain motion but allow the patient to move the digits within the limit at which such activity does not cause an increase in symptomatology. During this period, maintain the wrist in a dorsiflexed position by a plaster *splint. When the acute reaction* begins to subside, follow with increased active motion of the digits but never use passive forceful motions. At a much later date, assistance can be given by elastic functional type splints (clock-spring, knuckle-bender, etc.). A wooden exercise block and a large rubber sponge are most valuable adjuncts in helping to regain motion.

SPECIAL SITUATIONS AND PITFALLS

Severe Contractures (Over 60°) of the Middle (Proximal Interphalangeal) Joints of Long Standing and With Poor Volar Skin:

1. Do not expect full surgical correction.

2. Do not force the joint at the time of surgery, as to do so may cause rupture of the volar capsule and dislocation. If this oc-

curs, the chances are great that flexion contracture will recur, even to a greater degree.

3. If, at the time of surgery, it appears that there is not a reasonable chance of adequate extension being obtained even by postoperative splinting, it is best to do an immediate arthrodesis of the middle finger joint in approximately 45° of flexion. By doing so, some shortening of the finger will result, and this in turn will relax the soft tissues that are under strain.

4. When a middle-finger joint has suffered long-standing and severe flexion contracture (90° or more), consider amputation as a method of treatment. This can be performed at the time of the surgery if the patient has been forewarned. In most cases the proximal finger segment can be saved, the dorsal skin of the distal two segments being utilized for volar cover. If the fifth finger has both its proximal and middle joints in severe flexion contracture with poor volar skin on the palm and the finger, amputation should be carried out through the distal end of the metacarpal. Then all the dorsal skin of the finger is available to cover any skin defect in the palm.

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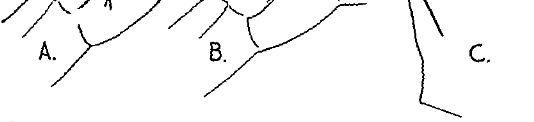

Fig. 7. (A) Incision used to approach thumb web for excision of involved fascia. (B) Closure by Z-plasty. (C) Suggested incision to use on radial side of thumb and thenar for fascial resection.

each case is of greatest importance. Surgery in the form of fasciotomy or fasciectomy is the only effective way of treating Dupuytren's contracture. Postoperative stiffening of the small finger joints is the major complication of operative treatment, and every effort must be made to prevent this disability or to minimize it should it occur.

The postsurgical objectives are to bring about complete healing of the wounds at the earliest possible time and to restore motion by active use of the hand once healing is complete.

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Contractura de Dupuytren: un Guida pro su Tractamento

Summario in Interlingua

Le plus grande problema in le tractamento chirurgic de contractura de Dupuytren es le prevention o le tractamento de rigiditate del articulationes in le digito minime. Tal rigiditate pote occurer sin reguardo al methodo chirurgic usate o al importantia del operation. Pro facilitar le selection inter fasciotomia, fasciotomia limitate, e fasciotomia radical in un caso particular, indicationes es proponite pro cata un del tres methodos. Es presentate un methodo pro registrar le location e le typo de affection fascial insimul con un simple maniera pro le expression graphic del limitation functional. Le accesso chirurgic de McIndoe es recommendate, e procedimentos es proponite que permitte le obtention del plus grande beneficio post le operation Es presentate un revista del complicationes e de lor tractamento, e le manipulation de aspectos "problematic" es discutite.

13

The Rheumatoid Hand

Lee Ramsay Straub, M.D.*

The multiplicity of deformities in rheumatoid arthritis has delayed progress in the surgical correction of any particular one. Most surgeons have had a natural reluctance to operate on even severely deformed hands, since it was felt that they might function better in deformity. This has been especially true in those patients who need their hands for assistance with crutch or cane. Because of this very worry, the internist managing the patient's arthritic complaints will rarely think in terms of surgical therapy. While this attitude is understandable, this author feels that an earlier approach to these problems may lessen the eventual surgical undertaking and provide better continuous function.

SYNOVITIS

The synovial and the subsynovial reaction in rheumatoid arthritis is the basic cause of deformity and disability in the rheumatoid hand. Synovium lines not only the joint spaces of the wrist and the hand but also the tendon sheaths and bursae. The changes in the synovium of the hand are characteristic of those seen elsewhere in rheumatoid disease. There is a thickening of the surface layers and great enlargement of the subsynovial cellular structure. There is infiltration of leukocytes and of plasma cells. The surface of the synovium may become redundant with racemose appendages, caused by the upheaval in the cellular structure. The normal synovial function of lubrication and nutrition is lost. This reactive synovium then distends the joint capsule, expanding and weakening the enclosing ligamentous structures. In the tendon sheath, the thickened synovium not only produces mechanical pressure on the tendon but its substance may develop within the tendon or penetrate the tendon from without so as to weaken the structure. The reflected portion of synovium on the tendon itself, equally abnormal, prevents the entrance of nutrient to the tendon. The tendon structure is altered thereby and weakened to the point of eventual rupture. Masses of this material attached to a tendon may prevent passage of the tendon through tight-fitting areas, such as under the pulleys in the fingers. Muscle spasm, particularly in the intrinsic musculature, now has the opportunity to produce grotesque deformities in these unstable joints. As the reaction of synovitis subsides, fibrosis occurs, not only in the sheath but in the surrounding soft tissues, particularly the capsules, and deformities become fixed.

Prevention of synovial reaction then would seem to be the logical way to forestall a great many of the difficulties in rheumatoid arthritis. Unfortunately, current means of therapy with steroids and other preparations have been successful only in a limited way and, often, of no assistance whatever.

"SNAPPING TENDONS"

Most instances of the snapping flexor tendon or tenovaginitis are nonrheumatic in nature. Some, however, are the result of a synovial thickening of rheumatoid arthritis,

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FIG. 1. Rheumatoid arthritis. Synovitis. (*Top*) Degeneration (gray areas) and necrosis (empty spaces) of collagen of extensor tendon of hand. Some palisading cells are seen at the margin of the necrotic collagen. (*Bottom*) Proliferative and exudative villous synovitis. The dark areas are foci of lymphoid and plasma cells. (Dr. Robert Mellors)

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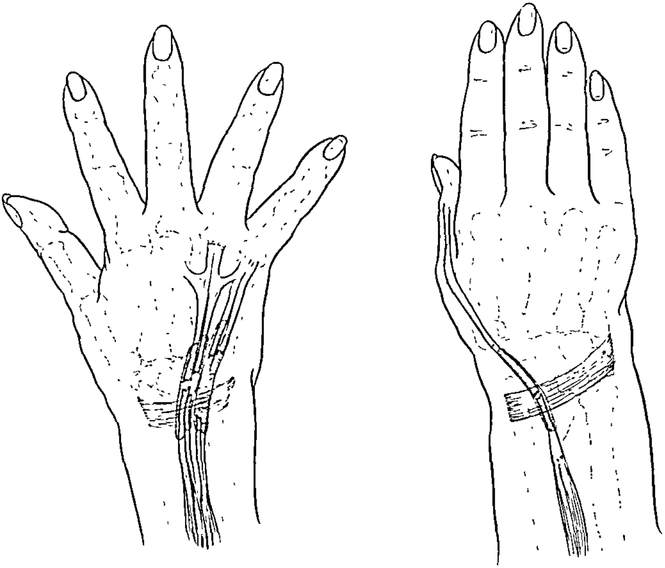

FIG. 2. (*Left*) Spontaneous rupture of the extensor tendons of the fourth and the fifth fingers
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shaggy nature of the synovium. For the acute or recent case, the best treatment consists of injection, after local anesthesia, of ½ to 1 cc. of hydrocortisone into the tendon sheath. Sterile preparation is essential. The 26-gauge needle is inserted with the bevel downward so that it will be deflected off the tendon surface. Usually it is easy to sense the position of the needle point and to pass it through the firm pulley structure. The fluid should flow readily and not be forced, for fear of misdirection, into the tendon body itself. If symptoms have been present less than 3 months, about 75 per cent of these patients will obtain relief with one or two injections. Repeated injections after that are useless if success has not been obtained. Far better improvement can be procured by surgical approach.

TECHNIC

Through a small curved transverse or oblique incision over the metacarpal head, dissection is carried down to the volar surface of the affected tendon sheath. The digital nerve on either side of the tendon with its accompanying blood vessels is identified. The pulley and the tendon sheath in the affected area are not merely incised but the volar portion is resected, so that there can

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as described above. In others, the exact etiology may be doubtful, with rheumatoid disease only suspected. In still others, the snapping tendon will be the first sign of rheumatoid change. Knowledge in this regard will be enhanced if the latex-cell agglutination and other new serologic studies are done when multiple tendons are involved in one individual.

Snapping may be present in any of the fingers or the thumb and may be indicated by a slight crepitant sensation on flexion or a definite snapping with locking of the finger in the flexed or the extended position. Usually a mass is found overlying the metacarpal head of the affected digit. In some rheumatoid patients, a soft crepitant slipping, palpated in this area, will indicate the

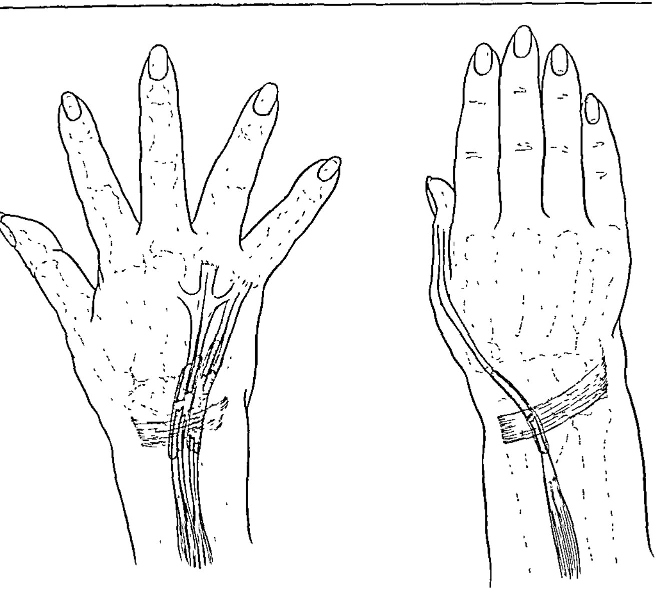

FIG. 2. (*Left*) Spontaneous rupture of the extensor tendons of the fourth and the fifth fingers in rheumatoid arthritis Note relations of transverse dorsal ligament to the dorsally prominent ulna. (*Right*) Spontaneous rupture of the extensor pollicis longus as it occurs following Colles' fracture and in rheumatoid arthritis. (After Straub & Wilson: J. Bone & Joint Surg. 38A:1209 & 1216)

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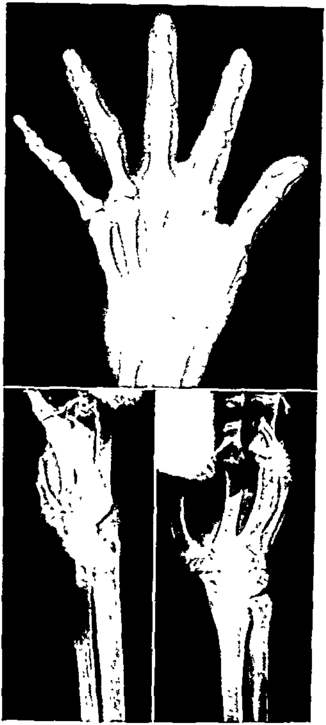


Fig. 3. Rheumatoid arthritis of the wrist Note subluxation and prominence of distal ulna

be no question of recurrence. This is don best with a local or regional anesthesia, s that free active motion of the tendon or ten dons invol e visualized. A tourniquet, while not essential. If the synovium i either on the surface of the e tendon sheath,

it is doubtful that the lesion is of rheumatoid origin. However, if shaggy masses of synovium are present on the tendon, they should be resected very carefully. There is a real danger of spontaneous rupture in tendons so affected if they are left untreated. The tendons wear away at points of pressure over bone or under ligaments such as pulleys.

SPONTANEOUS TENDON RUPTURE

Synovitis of the tendon sheaths occurs in the flexor tendon sheaths or bursae and in the extensor mechanisms as the extensor tendons cross the dorsum of the wrist. Spontaneous rupture of tendon occurs most often to the extensors because of certain mechanical features in that area. Spontaneous rupture of the flexor group does occur but with much less frequency. The mechanical factors producing spontaneous tendon rupture in the finger flexors of the rheumatoid hand are (1) pressure of the transverse carpal ligament on the weakened tendon; (2) pressure of a pulley; and (3) pressure and wear on some bony irregularity resulting from the arthritis in the carpal tunnel. The most common tendon ruptured on the dorsum of the hand is the extensor to the fifth finger. Close behind this, and usually next to go, is the extensor tendon to the fourth finger. The tendon of the extensor digiti quinti brevis passes through a tendon sheath separate from that of the extensor digitorum communis, at the dorsum of the wrist. Vaughn-Jackson has shown that an irregularity may a pear at the distal end of the ulna directly ying the tendon sheath to the fifth- extensors. This then through ovium and through ed ten- tually, there is a location a at the distal joint as the rheumato he pres- eumatoid sy eparation taneous ru ill follow additional pressu pture o xtenso descr y in

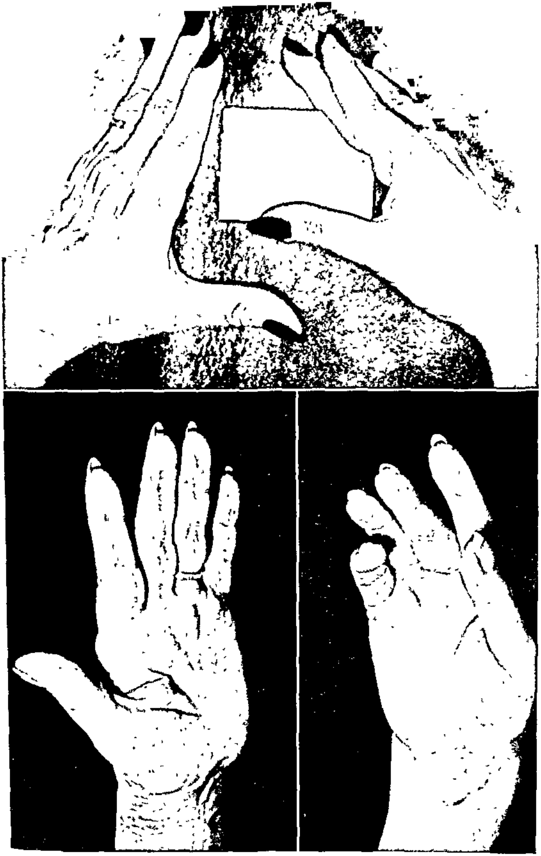


FIG. 4. These illustrations show spontaneous rupture of the extensor digitorum communis and the extensor pollicis longus of the right hand. Note dropping of thumb, long, ring and fifth fingers.

rope as "drummer's palsy." However, it may be a sequela of rheumatoid synovitis at the dorsum of the wrist. Eventual rupture comes at a point of wear at Lister's tubercle and directly under the transverse dorsal ligament. The serious residua of synovitis about the wrist suggest a more active early surgical management as good preventive medicine.

The Evaluation

Synovitis in the rheumatoid hand is readily recognized. On the dorsum of the hand it appears as a distinct soft swelling over the wrist with a narrow waistlike band of constriction at the site of the transverse dorsocarpal ligament. There may be separate nodes extending down the course of the extensor of the fifth finger, as this has a separate and a longer synovial sheath, but these sheaths continue distally only to the midmetacarpal level. The sheath of the long extensor of the thumb is limited similarly. In the volar aspect of the hand the evaluation is a little more difficult. Careful palpation bimanually of the palm and the volar aspect of the forearm will indicate the sensation of fluid flow beneath the transverse carpal ligament. This may be crepitant and earlier was termed *the compound palmar ganglion,* the classic description of tuberculous synovitis. After extensor tendon rupture has occurred, the affected fingers will drop 45 to 50° at the metacarpophalangeal joint. The thumb drops into the palm if the extensor pollicis longus parts. Limited extension of the fifth finger may still be possible after rupture of the extensor digiti quinti through a small slip, present frequently, that arises from the extensor digitorum communis. Loss of a flexor tendon will be indicated by specific examination of the finger flexors. Careful evaluation must be made of the flexor digitorum sublimis, as the action of the flexor digitorum profundus at the tip of the finger can mask a loss in sublimis function.

Treatment

Prolonged synovial thickening should not be left untreated. Early in its course there may be subsidence of the inflammatory activity by rest and by local use of steroids.

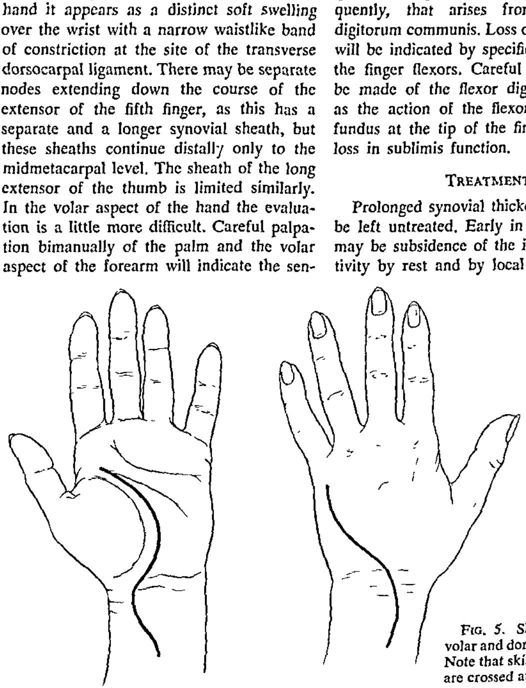


Fig. 5. Skin incisions for volar and dorsal synovectomy. Note that skin creases at wrist are crossed at about 60°.

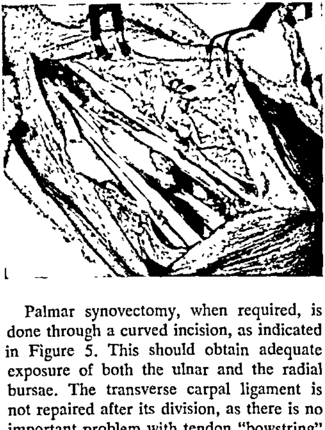


FIG. 6. (*Top, left*) Tenosynovitis of dorsum of wrist. Incision showing fascia overlying synovial mass. (*Top, right*) Synovial mass just distal to the transverse ligament which is seen above left. (*Bottom*) Note involvement of tendon in center by synovium and destruction of extensor tendons of the fifth finger (lower).

However, should there be no response to two or three synovial injections, done carefully, and no response to splinting over a period of 2 months, surgical synovectomy as a prophylactic measure should be seriously considered. A dorsal synovectomy is technically an easier procedure than the palmar and is needed more frequently. The dorsal skin incision should be curved or oblique. The transverse creases at the dorsum of the wrist should be crossed at about a 60° angle and not in a perpendicular direction. The dorsal carpal ligament is excised. The thickened shaggy synovium brown or yellow, is removed from the tendon by careful dissection. If the distal ulna is prominent dorsally, it should be resected by oblique osteotomy. Postoperative splinting of the wrist for soft-tissue healing is necessary for 10 days.

Palmar synovectomy, when required, is done through a curved incision, as indicated in Figure 5. This should obtain adequate exposure of both the ulnar and the radial bursae. The transverse carpal ligament is not repaired after its division, as there is no important problem with tendon "bowstring" deformity either on the volar or the dorsal aspect of the wrist. Careful inspection of the floor of the carpal tunnel, to make sure that there are no bony projections against the tendons, is done before closure.

Tendon Repair. Repair of a flexor dig-

itorum sublimis is not required if the profundus to that finger is still intact. If, as has happened often, both tendons have ruptured, it may be possible to make a tendon repair in the palm and thus avoid a free tendon graft. To repair profundus in the palm, an adjoining sublimis may be used as a motor, or the defect in the profundus can be bridged with tendon graft. If there is a single extensor-tendon rupture, side-to-side anastomosis to an adjoining extensor tendon is possible and is perhaps the most direct method of approach. However, with multiple involvement free tendon grafts may be required. Tendons can be obtained from the palmaris longus, from the plantaris longus or from extensor to the fourth toe.

It is of the utmost importance to protect the new tendon from any adverse pressure and to place it in a receptive soft-tissue bed.

The real emphasis should be on early synovectomy before tendon rupture occurs, to avoid the more complex reparative procedures.

ULNAR DRIFT

Ulnar deviation of the fingers at the metacarpophalangeal joint is extremely common in advanced rheumatoid arthritis. However, deformity is frequently out of proportion to the severity of the disease. It may follow soon upon the initial synovitis in the metacarpophalangeal joints. The supporting ligaments of these joints are invaded and expanded by the disease so that lateral stability is lost. As the hand continues in function, the normal force in flexion and in extension is a slightly ulnar direction rather than radial. The supporting hood of the extensor mechanism over the dorsum of the metacarpophalangeal joint is softened, and ulnar displacement of the extensor tendons from the tops of the knuckles into the ulnar valleys ensues. With fibrosis of soft tissues afterward, there is volar dislocation of the proximal phalanges on the metacarpal heads, and at this stage there is usually intrinsic contracture producing extension deformity at the middle interphalangeal joints The distal interphalangeal joints eventually go into flexion as the extensor mechanism becomes stretched and weakened by the arthritic process and is overpowered by the stronger flexor group. Ulnar deformity is greatest at the fifth finger, which frequently develops a right-angle deformity from the fifth metacarpal. Progress of the deformity may stop at any stage.

TREATMENT

Preventive measures consist largely of controlled exercises and splinting. The use

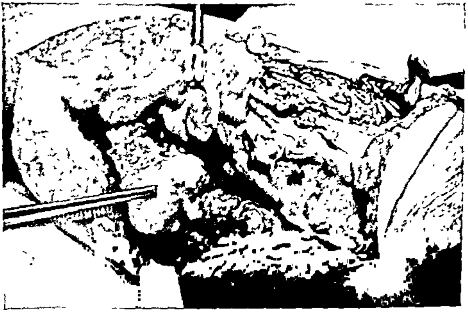
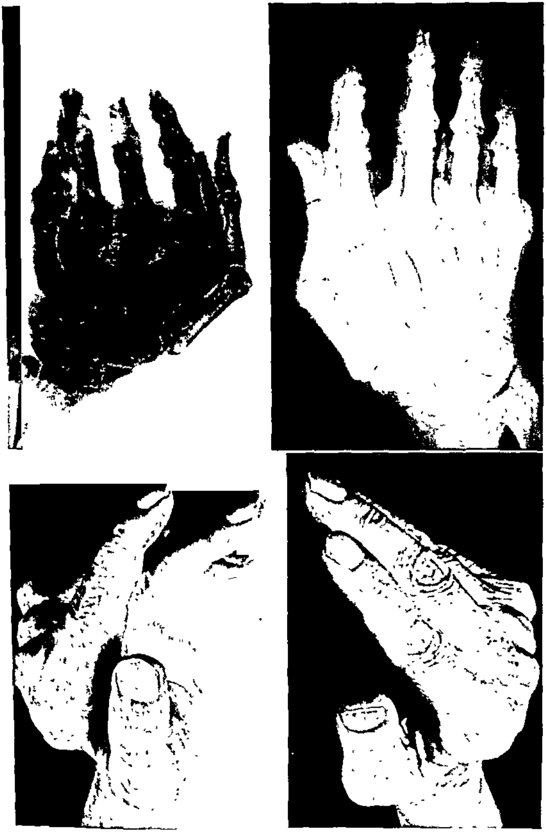


FIG. 7. Severe rheumatoid synovitis with loss of all extensor tendons except the index (same case as Fig. 4). Note extensor pollicis longus in clamp at right and resection of distal ulna at left.



FIGS. 8 and 9, same case. FIG. 8. (*Top*) Rheumatoid arthritis, severe ulnar deviation. Note dislocation of metacarpophalangeal joints. (*Bottom*) Postoperative photograph following resection of the metacarpal heads with the second, the third and the fourth fingers, fusion of the fifth metacarpophalangeal joint left hand.

of plastic splinting materials has provided a means of providing some splints that can be worn while actively using the hand. It is especially important to try to correct the deformity of the fifth finger, as this will act as a block to the deformity in the other fingers. However, such methods are only partially successful. Many surgical procedures have been devised to correct the deformity and with varying results. The author has found the following approach useful in the severely deformed hand.

Operative Technic

A dorsal transverse skin incision is used at the level of the metacarpal heads. The metacarpophalangeal joints are each approached through a radial longitudinal incision in the joint capsule. The heads naturally are prominent. The phalanges are dis-

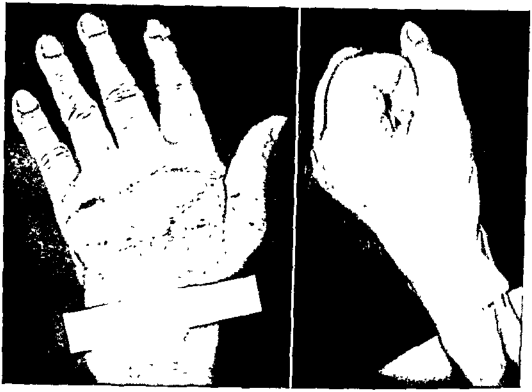


Fig. 9. Postoperative appearance following resection of metacarpal heads and capsular reconstruction of the metacarpophalangeal joints.

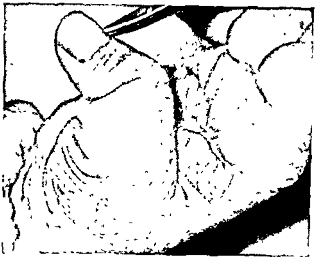


Fig. 10. Instability of the thumb in destructive rheumatoid arthritis.

located forward and cannot be reduced. The metacarpal head is resected in sufficient amount to allow a better articular relationship of the phalanx to the metacarpal neck. The extensor tendon, located and fixed in the ulnar valley of the given joint, is freed by an incision along its ulnar side. This allows it to be replaced over the dorsum of the reconstituted joint. Nothing is done to the base of the phalanx. Usually enough synovium is present to act as an interposing membrane, and no special interposition of tissues is necessary. The hood and the capsule then are closed on the radial aspect of the joint by imbrication. This forms a radial

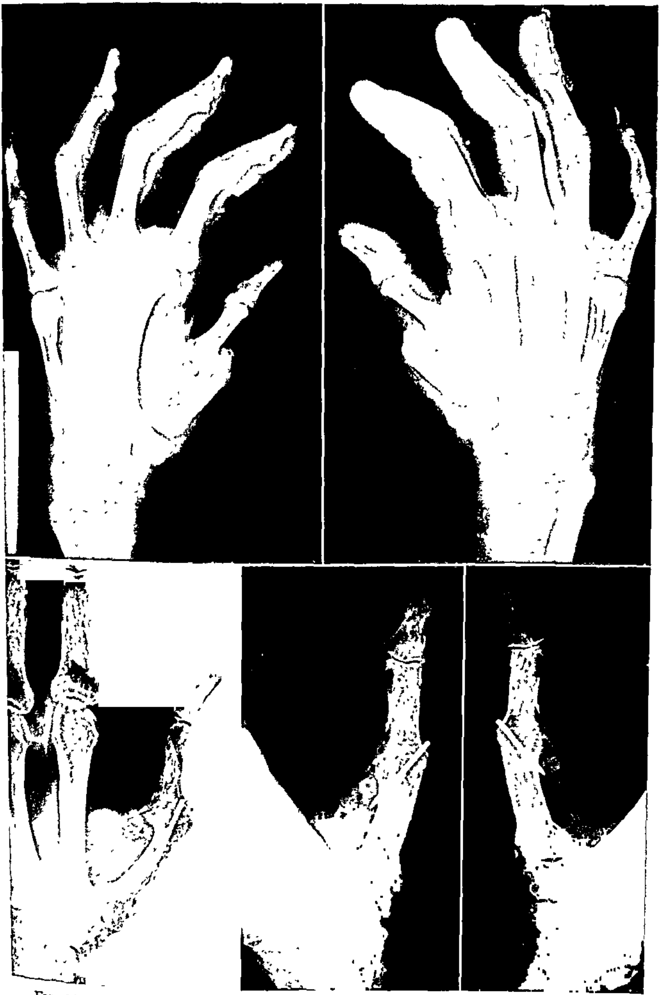


FIG. 11. (*Top*) Dislocation of the metacarpophalangeal joint of both thumbs in early rheumatoid arthritis. (*Bottom*) Postoperative arthrodesis metacarpophalangeal joint.

ligament to hold the extensor tendon over the top of the new metacarpophalangeal joint. At the fifth metacarpophalangeal joint, arthrodesis of the joint in the corrected position at 135° of flexion and 5° to 10° of abduction is done. This will serve as a permanent block against the other fingers. Fowler and Riordan have presented a method involving arthroplasty of these joints in a similar fashion and use the proximal portion of the lateral band as a means of anchoring the extensor tendon in the restored position. Their use of temporary Kirschner-wire fixation of the joints in the corrected position of flexion and slight radial deviation has proven to be effective. The Kirschner wires are left in place for 2 weeks; thereafter a program of graduated exercises, including hydrotherapy, is instituted, and, while these patients do not get a full range of motion in these joints, the restoration in function has been gratifying.

STABILITY AND ISOLATED DEFORMITIES

Certain types of rheumatoid arthritis may lead to extensive destruction around joints with complete loss of stability. Such arthritis has been termed *arthritis mutilans*. In the fingers and in the thumb this can cause serious loss in pinch and grasp function. When it affects the interphalangeal joint of the thumb, pinch must occur at the distal portion of the proximal phalanx rather than the tip of the thumb, and, when it occurs at the proximal interphalangeal joints of the fingers, there is no stability to lateral thrust or to pinch. Joints so involved are best treated by arthrodesis. At the interphalangeal joint of the thumb the thumb can be arthrodesed in the straight position. Arthrodesis of the proximal or the distal interphalangeal joints of the lesser fingers may also prove to be practical. These should be fused in the position of function; that is, the position most readily adapted by these joints when the hand is held in the position of rest. Kirschner wires provide a useful means of immobilization during healing. They should be buried and may be removed with local anesthesia after fusion is secure.

Dislocation of the First Metacarpophalangeal Joint. This may occur following rheumatoid arthritis. It may be a painful deformity and produce instability and weakness in grasp. The choice of treatment is fusion. Serious functional loss in the first carpometacarpal is rare in the rheumatoid hand.

EVALUATION OF THE RHEUMATOID PATIENT

In considering any operative procedure on the arthritic hand, it is wise to know a great deal of the patient's activities and wishes for the future. Once the program has been determined, it is well to explain it carefully to the patient and to give him time to consider whether there will be a total functional improvement or some loss of a very important ability. He should understand fully that restoration to normal is impossible. Limited gains only are sought, but in the hand a limited gain may be of real value.

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Le Mano Rheumatoide

Summario in Interlingua

Le problemas del mano rheumatoide non recipe le attention que illos merita, sin dubita a causa del multiple deformitates que le morbo produce in altere partes del organismo. Alterationes synovial es fundamentalmente responsabile pro un grande parte del occurrentias in le mano rheumatoide. Istos include le destruction del capsulas articular, le deformitate del deviation ulnar, le laceration de tendines, e le ruptura spontanee de illos. Multo pote esser effectuate in le prevention de iste disveloppamentos per medio de synovectomias que es meticulosemente executate ante le occurrentia del rupturas de tendines. Isto vale specialmente con respecto a synovitis afficiente les tendines dorsal del mano. Mesmo post le ruptura de tendines, lor reparo chirurgic es possibile. De facto, in le majoritate del casos le melior methodologia es probabilemente un tal reparo chirurgic. Le deformitate del deviation ulnar pote esser attaccate per methodos chirurgic con le distincte spero que le correction del deformitate e un melioration functional es attingibile.

Un aspecto del plus grande importantia es le evaluation del patiente individual con respecto a su requirimentos occupational e functional e etiam con respecto a su motivation.

Le objectivo del presente articulo es delinear le natura del reaction synovial rheumatoide e del deformitates que es producite per iste synovitis e proponer methodos de therapia chirurgic.

14

Giant-Cell Tumor of Tendon Sheath (Benign Synovioma) in the Hand

Evaluation of 56 Cases*

GEORGE S. PHALEN, M.D., LAWRENCE J. MCCORMACK, M.D., AND WILLIAM J. GAZALE, M.D.

The giant-cell tumor of tendon sheath is the second most common subcutaneous tumor occurring in the hand and is exceeded only by ganglions. These giant-cell tumors are referred to by many names, such as fibroma, endothelioma, myeloid tumor, myeloma, xanthoma, xanthosarcoma, myeloplax tumor, myeloid endothelioma, myeloxanthoma and benign synovioma. The term *giant-cell tumor of tendon sheath* is used commonly for this tumor, although the last term, *benign synovioma,* is the most accurate pathologically.

Numerous authors have reported series of giant-cell tumors of tendon sheaths, and they have emphasized that these tumors occurred more often in the fingers than in any other part of the body.

Fifty-six giant-cell tumors of tendon sheaths were found in a recent review of the clinical, hospital and pathologic records of 500 subcutaneous benign soft-tissue tumors in the hand treated at the Cleveland Clinic Hospital since 1947. The pathologic material from each of these cases was reviewed, and additional slides were made for microscopic study, using Masson stain for connective tissue and a special stain for hemosiderin pigment (modified Perls' reaction for iron salts). The clinical, the radiologic, and the operative data of each case were tabulated, and each patient was asked to return for re-examination.

CLINICAL FEATURES

The youngest patient in our series was 8 years of age; the oldest, 80 years of age. The table that follows shows the distribution

AGE DISTRIBUTION OF 56 PATIENTS AT ONSET OF GIANT-CELL TUMOR

AGE, YEARS	NO. OF PATIENTS
1-10	1
11-20	8
21-30	7
31-40	10
41-50	16
51-60	12
61-70	1
71-80	1
Total	56

in decades of the ages of our patients. Sixteen, the greatest number of patients, were in the fifth decade, and 38, or two thirds of the patients, were in the fourth through the sixth decades. Both sexes were involved about equally—25 males and 31 females—though in most of the reported series the women predominated slightly.

Giant-cell tumors of tendon sheaths are

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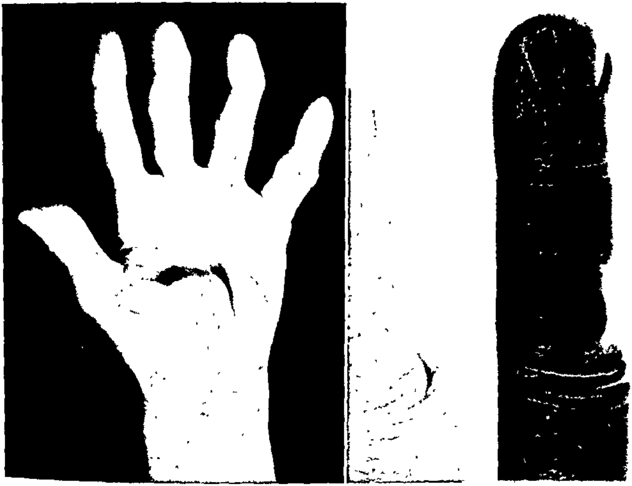
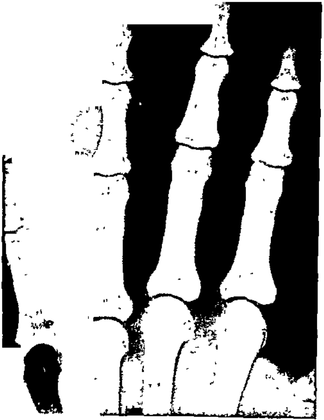


FIG. 1. (*Top, left*) Giant-cell tumor in the palm of the left hand. (*Top, right*) Giant-cell tumor over the dorsum of the middle phalanx of the left middle finger. (*Bottom*) Roentgenographic evidence that a giant-cell tumor has eroded the cortex of the middle phalanx of the ring finger.

known to involve the fingers more often than any other part of the body. Furthermore, the index and the middle fingers are involved more often than any others. In this series, 2 tumors were in the palm (Fig. 1, *top, left*), 7 in the thumb, 12 in the index finger, 18 in the middle finger, 11 in the ring finger and 7 in the little finger. An almost equal number of tumors were in the right and the left hands. One patient had a tumor on each hand, one on the volar aspect of the right thumb and another on the dorsal aspect of the left middle finger.

Of the 54 tumors in the fingers, 16 were in the proximal phalanx, 18 in the middle phalanx and 20 in the distal phalanx Seventeen (31%) of the 54 tumors were on the dorsal aspect of the fingers (Fig. 1, *top, right*), and 29 (52%) of the tumors were on the volar surface of the fingers. Eight of



the tumors within the fingers were strictly on either the medial or the lateral aspect of the fingers. In one patient, 2 tumors were present in a single finger: one on the dorsum of the distal phalanx and the other on the volar aspect of the middle phalanx. We have classified this as a single tumor, although at the time of surgery no connection was seen between the two growths. In another patient, the tumor involved both the volar and the dorsal aspects of the same finger; the tumor was excised in two stages for fear of impairing the vitality of the skin flaps by too extensive undermining.

From the data noted above, it appears that giant-cell tumors of tendon sheaths occur most frequently in the fingers of middle-aged people. Both the dorsal and the volar aspects of the hand are affected, but the surface on which the growth first appears cannot be used as a criterion for diagnosis.

SYMPTOMS AND SIGNS

The reported time between the appearance of the lesion and definitive surgery ranges from 2 weeks to 15 years. In this series, one patient stated that the tumor appeared overnight and that he sought treatment the next morning. Another patient stated that the tumor had been present for at least 10 years. The majority of these patients sought medical treatment sometime between 2 months and 3 years after they detected the growths.

Pain and tenderness are not prominent features of these tumors. Only 8 of the patients had pain at the site of the tumor; usually of a mild degree, the pain was aggravated by heavy work. The patient who noted the most pain was a woman who did arduous farm work.

In no case was there extreme tenderness over the site of the tumor. Seven of the 56 patients had slight tenderness; for example, one patient noted tenderness only when catching a baseball.

Giant-cell tumors of tendon sheaths produce disability only when the tumor becomes so large as to interfere mechanically with adequate motion of the joint or to displace and press upon the adjacent tissues. Only two patients had significant impairment of joint motion: in one patient, the tumor was at the proximal interphalangeal joint at the flexion crease and prevented complete flexion of that joint; in the other, the tumor was at the distal interphalangeal joint at the flexion crease, thus restricting flexion of the distal phalanx.

In no patient was there a rapid increase in the size of the tumor. Usually, giant-cell tumors of tendon sheaths grow so slowly that often they remain the same size for many years.

BONE INVOLVEMENT

The ability of giant-cell tumors to erode bone by pressure is well established. A review of the literature[4] disclosed 13 cases, of which only 4 involved bones of the hand. It seems likely that bone changes would be observed more often in association with giant-cell tumors of tendon sheaths if roentgen examinations were standard procedure for suspected lesions of this type.

The extent to which erosion takes place depends on the extent to which the tumor is free or limited in its expansion in directions other than toward the bone. Fletcher and Horn[4] have advanced the theory that if the tumor is bound down firmly by ligaments or tendons, it is more likely to erode through the bone cortex and to expand within the marrow cavity. Therefore, small tumors may cause distinct bone erosion, while, in the absence of such confinement, large tumors may cause only minimal erosion of bone. In this series, 22 roentgenograms were made; 4 showed evidence of bone involvement. The extent of this involvement was erosion only at the site of maximum pressure (Figs. 1, *bottom*, and 2). In none of the roentgenograms was there evidence that the bone marrow was invaded by tumor.

PATHOGENESIS

In the formation of giant-cell tumors of tendon sheaths, many authors have claimed

that trauma and infection played important roles. These tumors occur in the upper extremities several times as often as in the lower extremities; and the tumors involve the hands and the feet more often than any other part of the extremities. These observations seem to substantiate the view that trauma may be an etiologic factor.

There was no record of trauma in 48 of the 56 cases of this series. Four patients gave definite histories of trauma to the fingers at the subsequent sites of the tumors. An additional two patients gave histories of remote trauma that they believed might have been the cause of their tumors. Three other patients described activities in their occupations that might conceivably be regarded as causing chronic trauma to the involved fingers. In our series, there were 15 manual workers, such as assemblers, carpenters and packers, and 18 housewives; these two groups comprised approximately 60 per cent of our cases.

Infection was not considered to be an etiologic factor in any of the cases. From this review it is concluded that trauma and infection were not necessarily etiologic agents in the development of giant-cell tumors of tendon sheaths.

Geschickter and Copeland[3] stated that these tumors were derived from sesamoid bones, but histologic evidence has not confirmed such a possible origin.

Alteration of the lipoid metabolism has been suggested as the primary etiologic factor in the production of giant-cell tumors of tendon sheaths.[6] Patients with true xanthomas usually demonstrate an elevation in concentration of serum cholesterol, but those with giant-cell tumors do not.[6] Unfortunately, determinations of serum cholesterol were obtained in too few of our patients for us to be able to draw definite conclusions. However, we believe that elevated values for blood cholesterol do not accompany giant-cell tumors of tendon sheaths.

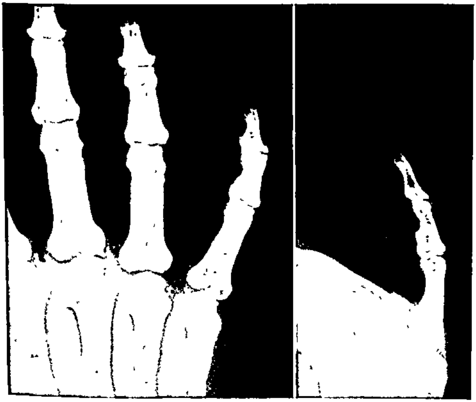


Fig. 2 Roentgenographic evidence that a giant-cell tumor has eroded the volar and the radial aspects of the middle phalanx of the little finger.

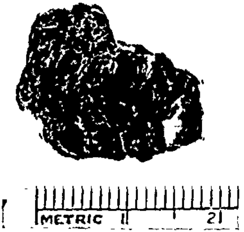
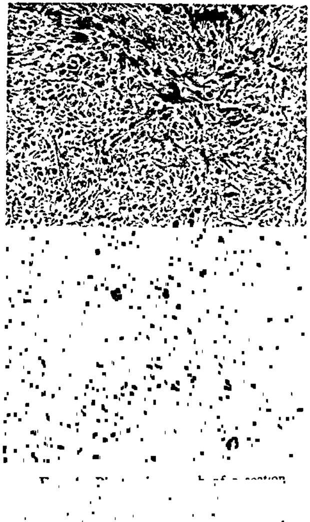


FIG 3. A freshly removed giant-cell tumor showing pseudoencapsulation; the multilobularity illustrates the difficulty of complete surgical excision.

These tumors are always benign. Stout[18] has stated that in no case of giant-cell tumors of tendon sheath in the hand had the tumor been proven to undergo malignant change. Rarely, when the tumor occurs in the soft tissue of the fingers, similar ones are found in the bone marrow of the phalanges The concept that the tumor may be malignant has been based primarily on the fact that infiltrative growth and rapid recurrence have been observed. In this series we observed no invasion of bone and no evidence of metastasis, either local or distant. As mentioned previously, in one of our patients 2 tumors occurred on different digits of the same hand. In two other patients multiple tumors were present in the same finger at different locations. In another patient there were multiple giant-cell tumors arising at the same site from different areas of the tendon sheath. These facts indicate a condition of multiplicity rather than of invasiveness or metastasis.



encasing the synovial cells, and several multinucleated giant cells. (Masson stain)

PATHOLOGIC FEATURES

The size of the tumors varies from a few millimeters to several centimeters in diameter. In our series, 7 tumors each were less than 1 cm. in diameter, and 1 tumor was more than 2.5 cm. in diameter. The tumors are firm, round, oval or lobulated subcutaneous masses that appear encapsulated by a dense fibrous covering formed by the compressed surrounding connective tissue (Fig. 3). Often the tumors have an elastic consistency. The color is grayish, mottled with red, brown or yellow, the proportion of these three colors varying respectively with the amount of hemorrhage, hemosiderin pigment or xanthoma cells present in the tumor.

Microscopically, the stroma of the tumor appears as a deeply eosinophilic collagenous connective tissue. This stroma is sparsely cellular in some areas but often seems to be devoid of cells or fibrillar structure. There is the widest variation in the proportion of stroma to tumor cells. The stroma sometimes appears as a fine meshwork and some-

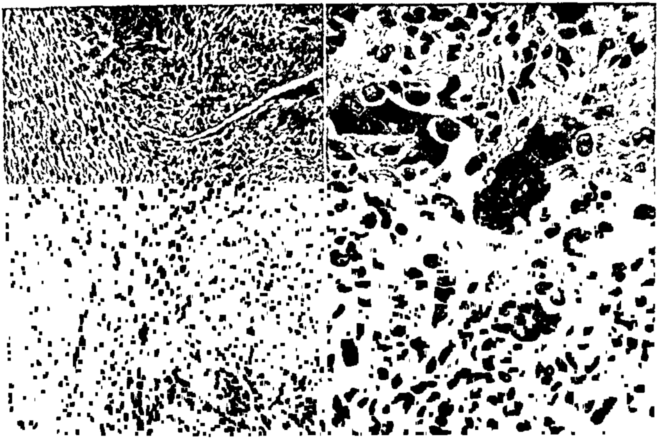


FIG. 5. (*Left*) Photomicrograph of a section of a giant-cell tumor (× 110) showing cellular hyperplasia and a small amount of collagen. (*Right*) Photomicrograph of a section of a giant-cell tumor (× 400) showing that the nuclei of giant cells are strikingly similar to those of the synovial cells.

times as broad bands or sheets of amorphous collagen in which the tumor cells are nested in widely separated lacunae. The process of fibrosis may proceed to such an extent as to leave nothing but fibrous tissue; this probably accounts for the reported "fibromas" of tendon sheath. According to Stout,[18] the dominating microscopic feature of these tumors is a disorderly fibrosis with phagocytic giant cells (Fig. 4).

The tumor may also contain myxomatous areas in which polyhedral spindle cells or stellate-shaped cells are separated by a mucinous matrix. Often these areas alternate with and show transition to fibrous areas.

We graded the fibrosis according to the amounts of fibrous tissue seen on microscopic sections of the tumors in our series: Grade 1 fibrosis is a scanty amount; Grade 2 fibrosis is a moderate amount; and Grade 3 is an unusually large amount of fibrosis. There were 15 tumors with Grade 1 fibrosis, 24 tumors with Grade 2 fibrosis and 17 tumors with Grade 3 fibrosis. In 19 tumors there were active fibroblasts that seemed to bear no relationship to the grade of fibrosis.

In addition, there was no relationship between the grade of fibrosis within a tumor and the age of the tumor. We estimated the age of the tumors by the duration of symptoms. Some of the relatively young tumors, of 3 or 4 months' duration, presented a Grade 3 fibrosis, while other tumors, of 4 or 5 years' duration, presented a Grade 1 fibrosis. Furthermore, in some of the older tumors there were many active fibroblasts.

There are three other types of cell commonly found in giant-cell tumors of tendon sheaths: the type, or synovial, cell; the giant cell; and the macrophage.

The synovial cells are the basic cellular

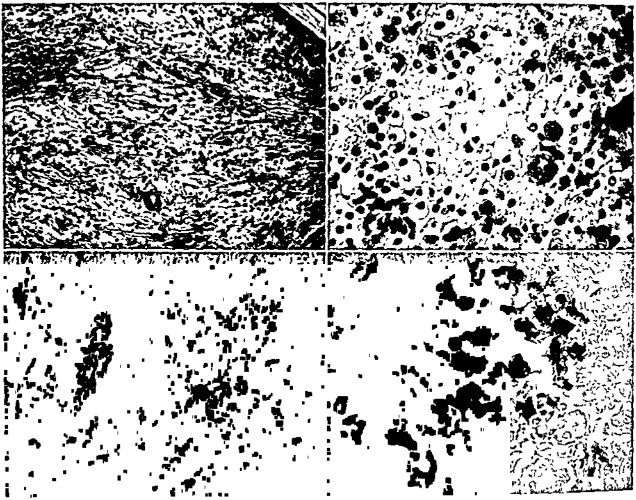


FIG 6. (*Top, left*) Photomicrograph of a section of a giant-cell tumor (× 110) showing the lipid-laden histiocytes or foam cells, characterized by dark-staining smaller nuclei surrounded by halos of foamy cytoplasm (*Top, right*) Photomicrograph of a section of a giant-cell tumor (× 400) showing characteristics of foam cells. (*Bottom, left*) Photomicrograph of a section of a giant-cell tumor (× 110) stained for iron The hemosiderin pigment is represented by the black areas (*Bottom, right*) Photomicrograph of a section of a giant-cell tumor (× 400) showing the hemosiderin pigment to be chiefly intracellular and present in the synovial cells as well as in the foam cells.

component of these tumors. Typically, they occur in groups separated by bands of collagen. The ratio of synovial cells to collagen is exceedingly variable. Some tumors are densely cellular in appearance, with only a light stromal network of interlacing strands of fibrous tissue separating the closely packed cells (Fig. 5, *left*). Usually, the cells are round to oval with rather scanty eosinophilic cytoplasm. The large nuclei are round or oval and often are indented. In the faint chromatin network there usually is a recognizable nucleolus.

The giant cells were a constant feature in all our cases. However, there was wide variation in the number of giant cells within different tumors As many as 40 giant cells may be seen in a single low-power microscopic field; the average is between 10 and 15 giant cells per low-power field in our series. In a few cases we found it necessary to search many fields to find a single giant cell. Giant cells were classified as rare in 11 tumors in our series. The giant cells, which vary in size, usually possess a homogeneous, abundant, slightly eosinophilic cytoplasm. Some contain 3 or 4 nuclei, while others have from 50 to 100 in a single cell.

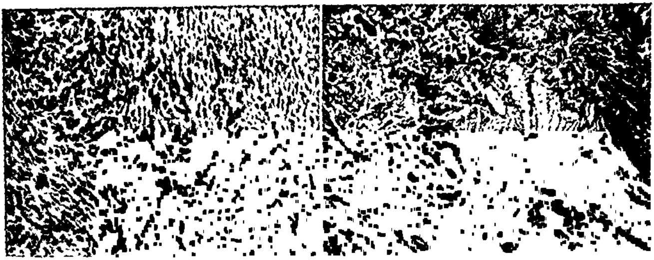


FIG. 7. (*Left*) Photomicrograph of a section of a giant-cell tumor (× 110) showing the synovial spaces or clefts lined by oval or flattened cells, imitating the arrangement of synovial cells in a normal tendon sheath. Note the collagenous stroma. (*Right*) Photomicrograph of a section of a giant-cell tumor (× 110) showing an area of necrosis within the tumor. Such areas were disclosed in 10 of the authors' 56 cases.

The nuclei are regular, slightly oval or round, and possess a fine, deeply staining chromatin network. In many instances the giant-cell nuclei closely resemble those of the synovial cell (Fig. 5, *right*), but in other cases they are smaller and more darkly staining.

Occasionally, the cytoplasm of the giant cell has a foamy appearance, due to the presence of lipoid droplets. Hemosiderin also may be present.

The foam cell, or macrophage, is not a constant feature of giant-cell tumors of tendon sheaths (Fig. 6, *top, left*). Frequently, foam cells occur in sufficient number to give the tumor a yellow color that has caused the tumors to be classified as xanthomas. Foam cells were found in all but 9 of the 56 tumors: they were rare in 7; and they were exceedingly numerous in 4. Usually they appear in small groups, but they may occur in larger masses that dominate the cellular pattern of the tumor. These cells generally have a granular, foamy appearance, and the nuclei are smaller and stain more deeply than those of the synovial cells (Fig. 6, *top, right*). Foam cells rarely have more than one nucleus.

Hemosiderin pigment was present in various amounts in all the tumors in our series (Fig. 6, *bottom, left*). This pigment was chiefly intracellular and was demonstrated within the stroma cells, the giant cells and the macrophages (Fig. 6, *bottom, right*). Hemosiderin pigment must result from the breaking down of erythrocytes that have extravasated into the tissues. Giant-cell tumors of tendon sheaths are not highly vascular.

Synovial spaces or clefts occur in giant-cell tumors of tendon sheaths. These slitlike cavities are lined by oval or flattened cells, and occasionally small tufts of these cells project into the cavities (Fig. 7, *left*). The synovial cells line these clefts and, in a way, imitate the arrangement of synovial cells in a normal tendon sheath. Clefts were found in 28 tumors of our series.

In 10 of the 56 tumors, areas of necrosis varying in size were observed on microscopic examination (Fig. 7, *right*). The presence or the absence of these areas apparently had no relation to the size of the tumor.

DIFFERENTIAL DIAGNOSIS

Since giant-cell tumors of tendon sheaths are the most common subcutaneous tumor in the fingers, exclusive of ganglions, the

physician must always consider these tumors in the differential diagnosis of any subcutaneous tumor in the hand. Usually, giant-cell tumors feel firm and rubbery, in contrast with ganglions, which usually feel truly cystic. If, upon aspiration of the tumor, some thick, glary, mucinous material is obtained, the diagnosis is unmistakably that of ganglion. Often, ganglions may also be transilluminated, revealing their true cystic nature.

Cavernous hemangiomas seldom are confused with giant-cell tumors. The bluish color of hemangiomas usually is seen through the skin, and the skin overlying the tumor may also be involved by the vascular tumor.

A true xanthomatosis seldom presents any diagnostic problem, since xanthomas are an integral part of the tendons themselves—usually the extensor tendons. The blood cholesterol content is almost always increased in a case of xanthomatosis.

Other tumors, such as myxomas, fibromas, lipomas and rheumatoid nodules usually require excisional biopsy to ascertain their true nature.

Giant-cell tumors of tendon sheaths must not be confused with giant-cell tumors of bone. The latter tumors usually cause expansion of the marrow cavity and thinning of the cortex. When a giant-cell tumor of tendon sheath involves adjacent bone, there usually is simple erosion of the bone from the pressure of the tumor. In rare instances the tumor may extend into the marrow cavity, but it does not expand the cortex.

When the cellularity of the soft-tissue giant-cell tumor is great and there is a large amount of cleft formation and tufting, it may be difficult to distinguish between this neoplasm and synovial sarcoma.

TREATMENT

Since giant-cell tumors of tendon sheaths are nonmalignant encapsulated growths, they are best treated by careful total excision. Adequate anesthesia, either general or local, and a pneumatic tourniquet about the upper arm to ensure a bloodless field in the hand are the two major factors in the prevention of recurrence. Often these tumors are lobulated growths; without the adequate visibility afforded by a bloodless field, the surgeon may fail to remove a small lobule of the tumor. The apparent capsule of these tumors has been shown to be infiltrated occasionally by cells characteristic of the lesion, and, in following a plane of cleavage, the capsule may be split, leaving behind some of the tumor cells.

Care must be taken in the removal of these tumors to spare the important anatomic structures in the fingers and the hand. Frequently, the digital nerves may be incorporated in the tumor; with careful dissection, the nerves may be spared (Fig. 8). In each of three patients of our series, a digital nerve was encased in the tumor; in all three complete excision of the tumor could be accomplished without sacrificing the nerve. In none of them was there any preoperative or postoperative impairment of sensation in the finger.

Occasionally it may be necessary to sacrifice a digital vessel. This will cause no circulatory impairment in the digit provided that the digital vessel on the opposite side of the finger is not damaged.

Local recurrences of the tumor after surgical excision occur rather often. Thannhauser and Magendantz[10] observed recurrences in as many as 37 per cent of the cases that they reported. There is no time limit for recurrence of the tumor; Stewart and Wright[17] reported a recurrence 34 years after initial excision of a giant-cell tumor of tendon sheath.

If the tumor arises between tendons and is compressed by them, the neoplastic tissue becomes adherent to all adjacent structures, which may render complete surgical removal difficult. The possibility of recurrence then becomes enhanced, in contrast with that condition in which the tumor grows out from a tendon into the subcutaneous tissues.

Of our 56 cases, adequate follow-up was obtained in 41 cases. The follow-up period ranged from 8 months to 10 years. Five of the patients reported to us with a recurrence of a giant-cell tumor of tendon sheath following excision of the tumor at another hospital. These 5 recurrent tumors were excised, and there were no further recurrences.

Eighteen patients had no recurrence 5 years or more after the original operation. Fourteen patients had no recurrence for from 8 months to 5 years after the original operation. In four patients who underwent the original surgery at Cleveland Clinic Hospital, recurrences of the tumors developed—one at 4 months, two at 2 years and one at 4 years after operation. We believe that it is safe to say that a case in which there is no recurrence 5 years postoperatively may be classified as a permanent cure.

When there is recurrence, local excision of the tumor should again be performed rather than more radical surgery. Complete removal of the tumor is facilitated when the tumor is small; therefore, patients are urged to have the tumor removed when it is first discovered rather than to wait until the tumor increases in size. Roentgen therapy is ineffective in the treatment of these tumors.

SUMMARY

Exclusive of ganglion, giant-cell tumor of tendon sheath is the most common subcutaneous tumor in the hand. The tumor is be-

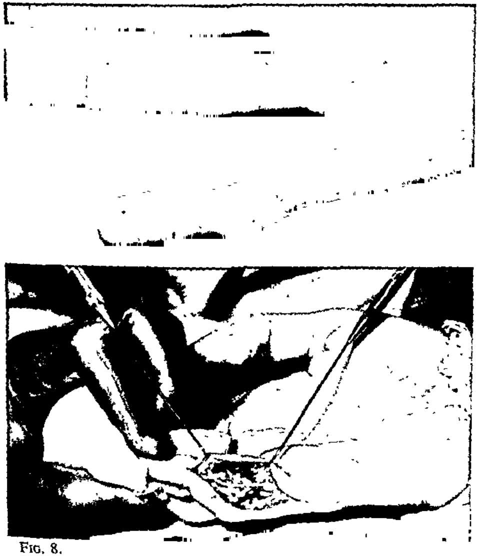


Fig. 8.
little fing(
operation, with the digital nerve already freed from the encasing neoplasm.

nign, painless, slow growing and, usually, a nontender neoplasm. Complete, careful, unhurried surgical excision is the preferred treatment. Recurrences after operative excision are not uncommon, and these recurrent tumors should be treated by another local excision. The microscopic features of these tumors have been discussed. Since these giant-cell tumors arise from synovial tissue, the term *benign synovioma* is most aptly applied to them.

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Tumor a Cellulas Gigante in le Vaina de Tendine del Mano (Synovioma Benigne)

Summario in Interlingua

Tumor a cellula gigante in le vaina de tendine es le plus commun tumor subcutanee del mano con le exception de ganglion Illo es benigne, nondolorose, e de lente crescentia. Usualmente iste neoplasma es nonsensibile sub pression. Le complete excision chirurgic, effectuate con meticulositate e patientia, es le tractamento a preferer. Recur-

rentias postchirurgic non es incommun e debe esser tractate per un repetition del excision local.

Es presentate un evalutation de un serie de 56 tal tumores. Le duo sexos esseva representate circa equalmente. Le majoritate del patientes se trovava in le quarte, le quinte, e le sexte decennio de lor vitas.

Le examine microscopic monstra que iste tumores prende lor origine in cellulas synovial. Assi le termino *synovioma benigne* pare esser le plus appropriate pro illos.

Section II

GENERAL ORTHOPAEDICS

15

Treatment of Slipped Upper Femoral Epiphysis With Mild Displacement by Internal Fixation in Situ

ALBERT J. SCHEIN, M.D.*

Ever since Wilson described internal fixation with a Smith-Petersen nail as a new treatment for slipped upper femoral epiphysis in 1938, the surgical treatment of such cases has become the accepted method of management. In the last several years, a number of relatively large series of cases from different institutions in various parts of the world have been reviewed that attest to the benefits of such treatment. Not all the methods of internal fixation have been identical (Hall, 1957; Klein, Joplin, Reidy, and Hanelin, 1953; Wilson, 1938 and 1949; Wiberg, 1948; Jerre, 1950 and 1957; and Howorth, 1957). The methods of internal fixation most popular at present include the Smith-Petersen nail; a thinner, more pointed nail—the Nyström nail—used chiefly in Scandinavia; multiple threaded wires or pins; and transepiphyseal autogenous iliac bone pegs. Each method has its advocates. The results of all are far superior to the older nonoperative methods in certainty of outcome and in reducing disability time and permanent disability. However, there are certain points in the surgical therapy that remain unsettled. This chapter reviews a series of cases treated at Mount Sinai and Bronx Hospitals, New York City, in the last 16 years. Of a total of 46 cases of slipped upper femoral epiphysis, 29 represented an early or a moderate slip treated by pinning *in situ*. The rest included cases of advanced chronic slip with marked deformity or severe acute slip with marked symptoms and deformity involving other methods of therapy. It is only with the 29 cases of mild to moderate slip pinned *in situ* that this chapter deals.

General statistics of the group are given in the following table. These are not in any way unusual or different from the larger reported series. This chapter is not concerned primarily with possible etiology, nor with diagnosis, but only with treatment, prognosis and early and late results of treatment.

* New York, N. Y.

STATISTICAL ANALYSIS OF CASES

Total patients	37	Total epiphyseal slips	46
Unilateral	28	Bilateral	9
Male	30	Female	7
Early slips (pinned *in situ*)	29	Acute massive or chronic marked slips	17
Right hip	22	Left hip	24

15

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Age Incidence	
Youngest (2 cases) age	7½ years
Oldest	16 years
Most between ages	11 & 14 years

Postoperative Follow-up Period	
Over 4 years	4
2-4 years	8
1-2 years	6
1 year or more	18
6-12 months	6
Hospital period only	5

DIAGNOSIS

Usually it is easy to make the diagnosis, even in the early stages, given a high index of suspicion. When pain and limp related to the hip or the knee regions of older children or adolescents occur, and suitable anteroposterior and lateral roentgenographic study is made and evaluated carefully, diagnosis is practically certain.

PROGNOSIS

The only lasting disability in these cases occurs when slipping has been allowed to advance with resulting deformity, often associated with arthritic and aseptic necrotic changes. These occur almost exclusively in cases that have been allowed to progress undiagnosed and, therefore, untreated, or in massive acute slips with marked deformity. It follows that if the cases can be detected early before such extensive acute or chronic slips have taken place and are treated effectively and permanently in such a way as to prevent further slip, without inducing other deformity or disability, the greatest blow will have been struck against the permanent crippling disability that may otherwise result.

OPERATIVE AND POSTOPERATIVE MANAGEMENT

The cases of mild, and even a few of moderate, displacement have been treated uniformly in this series by operative means as promptly as possible (short of emergency surgery) by internal fixation with a Smith-Petersen nail. Early mobilization follows, including early ambulation with weight-bearing, usually within 2 weeks after operation, on crutches. As soon thereafter as desired by the patient, after wound-healing is complete, full weight-bearing without crutches or artificial support is permitted. Usually within 2 to 3 months the boys and *the girls are back on full duties, including* school, games and normal play, though usually it has been advised that competitive athletics be avoided for a 6-month period.

A Typical Case

Case I. R. H., Negro, male, age 13. This was a case of bilateral mild slip in a boy of the Fröhlich type with a history of 1 to 2 months of limp and pain in both hips. Roentgenograms taken in October, 1949, showed bilateral early slips of the upper femoral epiphyses (Fig 1). Bilateral Smith-Petersen nailing was performed on October 29, 1949, with excellent position and fixation in both anteroposterior and lateral views (Fig. 2). The patient was up walking with crutches and partial weight-bearing on November 11, 1949. Crutches were discarded within 2 to 3 weeks. He was discharged from the hospital on November 13, 1949. Follow-up showed uneventful healing without further slip or difficulty. Roentgenogram taken 1 year later (Fig. 3) showed epiphyseal lines almost fused. Clinically, the patient was entirely well, and the hips were normal

Selection of Cases

Selection of cases for this treatment varies somewhat in different institutions. It has been said (Wilson, 1938; Klein *et al.*, 1953) that any case in which slipping has progressed beyond one third of the transverse diameter of the base of the head in the lateral view (approximately 1-1½ cm.) is no longer suitable for pinning *in situ*. In this series, several cases were pinned in which deformity had progressed beyond this point. In a few, subtrochanteric osteotomy was contemplated later after termination of growth and fusion of the epiphysis. This proved uniformly to be unnecessary by the

FIGS. 1 to 3, Case 1, age 13. A routine case of early bilateral upper femoral epiphyseal slip. FIG. 1. (*Left*) Anteroposterior and (*right*) lateral preoperative roentgenograms.

FIG. 2. Early postoperative roentgenograms showing excellent fixation and position. (*Left*) Anteroposterior view. (*Right*) Lateral view.

good clinical result after a year or more, even in cases in which the degree of slip had reached between one third and one half of the transverse width of the base of the head. The complete relief of pain and spasm, despite presence of slight shortening and some restriction of motion in internal rotation, did not warrant further surgery. Even loss of internal rotation and some flexion, unless extreme, may be treated, according to Heyman *et al.* (1957), by excising the anterior bump formed by the angle between the neck and the displaced head without loss of continuity by osteotomy and without risk of aseptic necrosis. Thus, in this series, all cases of slipped upper femoral epiphysis were pinned *in situ* unless they had slipped

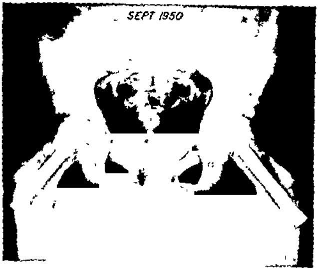


FIG. 3. Anteroposterior view 1 year later showing no change in position or fixation and early obliteration of the epiphyseal line.

more than one third and almost one half of the head diameter. Hall (1957) has found similar results in slips up to one half of the head diameter.

Technical Details of Pinning

The technical details of the pinning are important. A guide wire is introduced repeatedly if necessary, and the position is checked by roentgenogram in two planes until it is proven to have passed through the neck and into a substantial part of the head. This is more difficult than directing a similar wire in fracture of the hip in an adult. The more the head has slipped backward and downward, the less target there is for accurate placement of the wire both in the neck and into the head. If it follows the center of the neck, it must enter the anterior part of the head. If much slip is present and the wire enters the center of the head or the posterior portion, it may miss part of the neck altogether. In part, this may be avoided by starting the guide wire well anteriorly on the femur below the trochanter and directing it somewhat obliquely backward in the neck to enter the head. On the other hand, it does not require as much of a hold on the head by the nail to render the fixation secure. The solidity of the bone in these children and the partial connection of the femoral head to the neck are such that even a small penetration of the nail into the anterior portion of the head—as much as 1 cm.—suffices to get adequate internal fixation so long as the nail is not overgrown. Of course, the deeper the penetration that can be obtained to the center of the head without perforating the joint or the acetabulum, the longer will it take the growth of the upper femoral epiphysis to overgrow the nail, so that this is the aim of insertion.

Complications

Complications may be discussed under several headings.

Overdrive of the Nail

It has been stated that overdrive of the nail may result ultimately in arthritic and aseptic necrotic changes. This overdrive occurred in two of the author's cases without any untoward end-result.

Driving Away of the Epiphysis

The driving away of the epiphysis from the femoral neck by the nail has been described by Wilson (1949), by Jerre (1950) and by Hall (1957). It did not occur in any case in this series; the only time that this complication was encountered was in a case of acute severe slip that had been reduced by manipulation and then nailed a week later. Even then, the diastasis caused by the hyperabducted, or valgus, position of the head filled in as described by Jerre with a good end-result. In mild and moderate slip cases, without acute superimposed slip, the nailing itself caused no tendency to separate the head and the neck in this series. Jerre (1957) described five cases of this complication, with the diastasis measuring 5 mm. to 1 cm. in one case, treated by early weight-bearing with early disappearance of the diastasis and good end-result. Hall (1957) described two such cases without loss of a good end-result.

It is because of this that the Nyström nail or the threaded pins of Moore or similar type has been suggested. The author has not found them to be necessary in the type of case under discussion. However, he believes that such pins have a place in pinning cases of massive acute slip, where they may be drilled in after reduction rather than hammered in. They also have a place in fixation when cervical osteotomy and open reduction have been done. The difficulty of placing at least three such pins in the narrow target of the neck and the anterior femoral head without penetrating the joint or the acetabulum has prevented the author from using this method routinely in the chronic early or moderate slips.

Slipping Back of the Nail

The slipping back of the nail, once it is placed, is another possible complication

mentioned by Jerre (1957). In his series of 79 cases he found twelve in which such "gliding" took place. In seven, this was enough to lose fixation. Three had to be reoperated upon to reintroduce a nail, while one slipped later with a poor result that required osteotomy. The others were near the end of growth by the time the slip was noted, and nothing had to be done. In the author's series, such slipping occurred in a single case, where the nail had been overdriven and had to be replaced at the primary operation by a slightly shorter one in the same channel. This resulted in a slight back slip, not sufficient to endanger the fixation, and the end-result was excellent. This complication indicates the importance of measuring the length of the nail accurately and confirming the exact position of the guide pin so that the nail does not have to be withdrawn. Its best fixation in the cortex of the femoral head may be lost by such withdrawal and reinsertion.

Growth Beyond the Nail

This is another possible complication of treatment, and it is especially important if the patient is in the younger-age group with much epiphyseal growth remaining in the femoral epiphyseal plate. Klein *et al.* (1953) reported six cases in which this occurred (out of 55 early slips noted). Their youngest was 11 years and 8 months old at pinning. None of them came to any harm in the remaining growth period, which was relatively short by the time the overgrowth occurred. Jerre reported four cases of this type in which overgrowth was enough to leave the nail entirely out of the head. In two of them, near the end of the growth period, nothing had to be done. In the other two, the epiphyseal line was said to be still open, and they underwent reoperation. In the author's series, which is unusual in that it included two very young children aged 7½ at the time of pinning and one other aged 11, a total of three hips have shown overgrowth of the nail so that the nail no longer is in the head at all. The fourth, in a bilateral case, will probably soon overgrow. In none of these has any trouble resulted, though one is still in the growth stage, and there may be potential danger. The first, aged 7½ at the time of pinning, was followed 10 years until the growth of the epiphyseal line ended. It was 4 years after pinning that overgrowth was noted, but no further treatment was given, though he was only 11½ at the time. No difficulty occurred, and the epiphyseal line fused normally thereafter.

Case 2. I. G., white, male, aged 7½. This boy was first admitted on December 1, 1943, because of limp and pain on running related to the lift hip. Roentgenogram showed early widening of the metaphyseal epiphyseal plate region on the anteroposterior and very early slip on the lateral. Because of his age, he was treated in a hip spica for 2½ months and was discharged because of intercurrent measles. When readmitted, the diagnosis was even more clear by roentgenogram, and Smith-Petersen nailing was done on February 23, 1944. He was allowed to bear weight 2 weeks postoperatively, and he discarded crutches within a few weeks. He was subsequently free of symptoms (Figs. 4 & 5). Roentgenograms were made at intervals as growth continued. Four years later, overgrowth had occurred so that the nail was just proximal to the epiphyseal line (Fig. 6). Despite this, possibly due to beginning bone growth across the line as the nail receded, there was no further slip, nor any late symptoms. Ten years later, roentgenographic study (Fig. 7) showed final obliteration of the epiphyseal line, the nail at least ½ inch distal to the epiphyseal line, and excellent position and alignment in a hip without any clinical abnormality.

In summary, this boy of 7½ overgrew the nail but not until he was past 14, when little epiphyseal growth remained. He had no further slip and made an uneventful recovery.

Case 3. J. G., white, male, aged 11. This boy was admitted on May 23, 1951, complaining of increasing pain in the right hip following a fall 1 month before. There was limp and restriction of motion of the right hip. Roentgenogram showed a typical early slip of the right upper femoral epiphysis (Fig. 8). The hip was pinned by Smith-Petersen nail on May 25, 1951. The patient was discharged walking on crutches on the tenth postoperative day (Fig. 9). When last seen, on April 2, 1954, about 3 years later, he had grown a great deal in height, being then

FIGS. 4 to 7, Case 2, a boy aged 7½ at onset of clinical symptoms. (Left) Anteroposterior view of early slip of left upper femoral epiphysis. This shows only slight widening of epiphyseal line and metaphyseal irregularity. *(Right)* Lateral preoperative roentgenogram.

FIG. 5. Early postoperative roentgenograms showing excellent fixation and penetration of the nail (*Left*) Anteroposterior view. (*Right*) Lateral view.

FIG. 6 Three years after operation. (*Left*) Anteroposterior view. There has been overgrowth of the nail, the inner end of which is at the epiphyseal line. Although the latter appears to be thin, it is still in a stage of growth. (*Right*) Lateral view.

Fig. 7. Ten years after operation. *(Left)* The nail has been completely overgrown. The epiphyseal line is obliterated on both sides but is more dense and more completely ossified where the nail penetrated it. *(Right)* Lateral view 10 years after operation showing the same earlier and more complete osseous bridging at the site of perforation of the epiphyseal line.

Figs. 8 to 10, Case 3. Boy, aged 11. Fig 8. *(Left)* Anteroposterior view preoperatively of the right hip shows early epiphyseal slip of upper femoral epiphysis. *(Right)* Semilateral view at the same time.

over 14 years of age. There were no symptoms related to the right hip, but there was a tendency for it to flex in slight external rotation. No actual restriction of motion was present. Roentgenogram (Fig. 10) showed that overgrowth had occurred so that the nail end lay at the epiphyseal line and was no longer in the femoral head. However, the upper femoral epiphysis looked fairly well closed, and it was considered that there was no danger of further slip. The opposite hip showed the epiphyseal line to be thin but open, so that the right had fused somewhat prematurely. Nevertheless, no shortening had resulted.

The last of these, a bilateral case, is now 11 years old and has overgrown the nail on the first side, 2½ years later, while the side that underwent operation later is still fixed by the nail into the head part way. It, too, will soon be overgrown. Clinically, this boy is free of symptoms, but this cannot yet be regarded as an end-result; there is a possibility of further surgery, as the epiphyseal plates are still open.

Case 4. B. R., white, male, age 7½ at first admission. This boy was first admitted with a

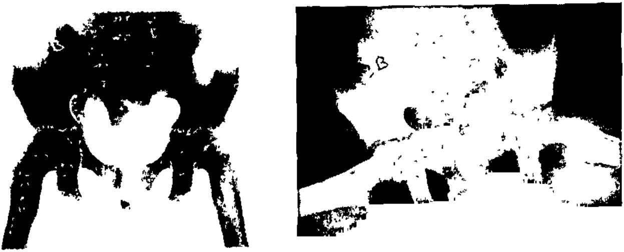
FIG. 9. (*Left*) Early postoperative roentgenogram, anteroposterior view, showing excellent fixation and position of Smith-Petersen nail. (*Right*) Lateral view, early postoperatively, showing full penetration of the nail.

FIG. 10. Three years later. Anteroposterior view shows overgrowth of the nail. However, at age 14 the epiphyseal lines are almost closed, even on the unoperated side. On the slipped side the epiphyseal line is obliterated.

left-sided limp of 2 weeks duration. Clinical and roentgenographic examination indicated an early slip of the upper femoral epiphysis. He was *pinned in situ on November 29, 1954 (Figs. 11 & 12)*. The postoperative course was uneventful, and he was discharged weight-bearing with crutches on the twelfth postoperative day. Crutches were discarded 3 to 4 weeks later, and the hip has remained entirely asymptomatic ever since. However, during observation and repeated checkups, the patient's parents were informed of a possible slipping of the other (right) hip.

On May 20, 1956, the boy was readmitted, then 9 years old, because of new limp and pain *in the right hip. Roentgenogram (Fig 13)* showed a very early slip on the lateral view of the right hip, and considerable overgrowth of the left hip, so that the end of the nail was only ⅛ inch into the femoral head. The second hip (right) was pinned on *May 21, 1956. The* patient was ambulatory on crutches 10 days postoperatively and discharged walking. Within 6 weeks the crutches were discarded, and further convalescence was uneventful.

In September, 1956, almost 2 years after the pinning of the left hip, he was seen for transient limp related to this region. By that time the nail had overgrown so that a roentgenogram showed the nail almost entirely in the femoral neck with only a corner in the head (Fig. 14). No additional slip of the epiphysis could be seen. After consultation, in which surgery for replacement with a longer nail was considered, he was *watched closely. The limp and the pain* disappeared completely. When last seen, on September 19, 1957, he had grown a good deal. He



FIGS. 11 to 15, Case 4, a boy of 7½ at the time the slip of the left upper femoral epiphysis was first noted. FIG. 11 (*Left*) Anteroposterior and (*right*) lateral preoperative views.

FIG. 12. Early postoperative pinning of left hip. (*Left*) Anteroposterior view showing excellent placement and penetration (*Right*) Lateral view.

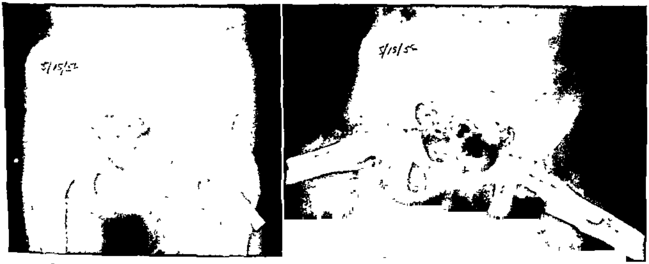


FIG 13. (*Left*) Anteroposterior view 1½ years later. Early slip noted on right side. On the left, overgrowth of the nail is occurring, but it is still partly in the femoral head. (Right) Lateral view of both hips showing the same status 1½ years after pinning of the left hip and early slip on the right.

FIG. 14. (*Left*) Early postoperative anteroposterior roentgenogram after pinning the right hip 4 months previously and the left hip 22 months before. There has been further overgrowth on the left. The nail lies with its inner end at the epiphyseal line. At this time some limp on the left had occurred. (*Right*) Lateral view of both hips at the same time as at *left*. Note some sclerosis and bone formation in the track of prior penetration of the nail on the left in the femoral head adjacent to the epiphyseal line.

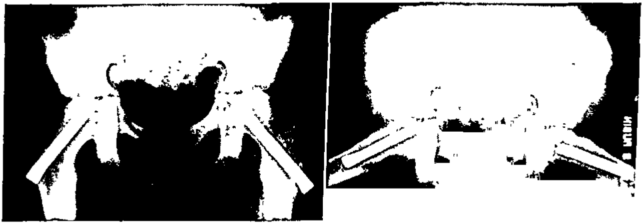


FIG. 15 (*Left*) One year after Figure 14 The boy is now 11, and it is 34 months and 16 months, respectively, since the pinnings on the left and the right hips were done. Both epiphyseal lines show growth. On the left, the nail is within the neck. Note sclerosis along track in head. (*Right*) Lateral view at same time as at *left* showing the same findings. Note on the left that some bone bridges the epiphyseal line, rendering it safe from further slip, although not stopping growth noticeably.

was entirely free of symptoms in both hips. The legs were equal in length. Motion in both hips was normal Roentgenograms (Fig. 15) showed that, on the left, the nail was completely in the neck but that bony trabeculations now crossed the epiphyseal line from head to neck, thus in all likelihood preventing further slip.

Though fully active, further observation was suggested by roentgenograms and clinical examination until full growth should be reached

It is in this group of very young cases that definitive fusion of the epiphyseal line by bone pegs, according to Howorth, may obviate the worry over a later slipping after complete overgrowth of the nail. However, it must be recognized that this would be at the expense of growth which, in a very young child, may result in ½ to 1 inch of shortening, as well as a more prolonged convalescence and the necessity of an intra-articular operation with its attendant risks. It would seem to be preferable to fix the slipped epiphysis by nailing as usual and to watch carefully for symptoms or signs of recurrence, when surgery to extend or to replace the nail might become necessary.

There is an additional rationale for not operating in spite of overgrowth of the nail. Siffert (1956) described the effects of longitudinal transfixion of an epiphyseal line by a wire in rabbits. This did not stop epiphyseal growth, but as growth occurred, the path made by the wire was replaced progressively by new bone. It has been noted clinically that single, longitudinal, central penetration of epiphyseal plates by nails or wires does not produce cessation of bony growth. In this series, as in others, the epiphysis has continued to grow. This depends on the patient's age and nearness to the end of epiphyseal growth. It is true that in more severe epiphyseal slips, premature union at the epiphyseal line has occurred. Wilson (1949) felt even that the nail expedited such union, so that epiphyseal fusion would occur earlier than expected. However, it appears that in mild chronic slips, such early union does not follow and that epiphyseal growth continues for the usual time. But, as the epiphysis overgrows, formation of a channel of penetration by the nail will result in ossification in the channel bridging the epiphyseal line and thus prevent further slipping, like primary bone-grafting. This is probably the reason that further slipping of the epiphysis has not occurred in spite of overgrowth of the nail during the active growth period in the author's cases. It also suggests that in the younger-age groups, where this may be a factor at the time of insertion of the nail, additional drill holes should be made across the epiphyseal plate to hasten additional bony bridges, while maintaining good fixation by the nail. Thus, by the time overgrowth has occurred, the epiphysis should be fully united or stabilized on the femoral neck without risk of further slipping.

Late Subtrochanteric Fracture

This occurred in one case in the author's series. It was the result of considerable violence in football. Usually it can be treated by applying a McLaughlin plate to the Smith-Petersen nail for internal fixation of the new fracture. Some believe that this is an indication for routine removal of the nail after epiphyseal growth has stopped and the nail no longer serves its purpose. The author has not done this routinely, reserving removal for those in whom symptoms of irritation about the nail have occurred.

Late Aseptic Necrosis or Arthritis

This also has been observed (Hall, 1957) in 5 per cent of slipped epiphyses of a mild degree pinned *in situ*. It has not taken place in any of the cases followed long enough in this series, although it is possible that it may have in a few not followed long enough.

Optimum Time for Weight-Bearing

There is still some disagreement as to when weight-bearing should be permitted after operation has been performed. In 1956, Scott, in a review of the literature, said that, after the Howorth procedure or the pinning according to Wilson, he forbade weight-bearing for approximately 3 months and restricted activities for another 3 months. Others have held that early weigh-bearing on crutches within 2 to 3 weeks was permissible and that crutches could be discarded within 1 month (Klein *et al.*). Jerre (1957) permitted early weight-bearing

within 2 weeks postoperatively. Hall (1957) found no cause for regret in early weight-bearing (2 weeks) either after Moore pin fixation or Smith-Petersen nailing, provided that no change in position had occurred by rotation, traction or manipulation. In such cases, where the position has been changed, weight-bearing should be deferred for 2 to 3 months. Cleveland *et al.* (1951) allowed weight-bearing with a brace to prevent external rotation.

In the author's cases, with the exception of special instances in which wound healing was complicated by hemorrhage or drainage, or the one case in which the nail slipped back, early weight-bearing was allowed within 2 to 3 weeks. This is the usual time for wound healing to become well established. Although this began with crutches, it progressed rapidly to unsupported weight-bearing within an additional week or two, so that by a month or 6 weeks most patients were walking without external support. The author feels that no harm came to any of these patients. No further slip, loss of fixation or arthritic change was demonstrable. This is one of the great advantages of Smith-Petersen nail fixation—convalescence, and hospitalization with its attendant expense, are reduced to a minimum. Thus, there seems no reason to defer weight-bearing and early resumption of all but the most strenuous athletic activities. This has been done and is still being done in some institutions. There is no need for bracing.

SUMMARY AND CONCLUSIONS

1 A group of 29 cases of early and moderately advanced chronic slip of the upper femoral epiphysis has been reviewed These were treated almost uniformly by pinning with a Smith-Petersen nail and early weight-bearing.

2. In general, the results have been excellent, consistent with the degree of slip at the time that the diagnosis was made. Cases showing slips up to almost half the diameter of the base of the head in the lateral view have done fairly well clinically without additional surgery, although the future development of arthritic changes may still vitiate a late or adult life end-result. Certainly any slip of one third of the diameter of the base of the head or less may be nailed safely *in situ.*

3. The complications have been reviewed and compared with similar findings in the literature. The incidence, the management and the prognosis have been considered.

4. Early weight-bearing at 2 to 3 weeks after operation is definitely permissible after such pinning, provided that there is no change in the position of the slipped epiphysis obtained by reduction. In a few cases in the literature, even where a slight diastasis had been produced between the head and the neck, if good position and fixation were obtained by the nail, early weight-bearing was still considered to be helpful in closing the diastasis without risk.

5. Incidence of aseptic necrosis and arthritic change, at least in the early years after such treatment, is negligible in this type of case.

6. Follow-up of several cases occurring in very young children at the time of pinning shows that overgrowth of the nail, with lost internal fixation, need not jeopardize the end-result. A filling-in of the nail tract by new bone produces a living bone graft across the epiphyseal line. This gives enough fixation so that further slipping is unlikely, even though growth continues and the epiphyseal line remains open for some years. However, in view of verbal reports of such late slipping after overgrowth, none of which has been found in this series or in the literature, it would seem to be advisable to drill across the epiphyseal plate at the time of fixation to encourage earlier union, and to follow cases carefully to detect any possible need for replacement with a longer nail.

7. The author's results are similar to and consistent with the reports of other series treated identically. This method of management is preferred for the slow, early or moderate slipping epiphyses.

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Tractamento de Glissate Epiphyse Femoral Superior per Medio de Fixation Interne in Sito con Leve Grados de Displaciamento

Summario in Interlingua

Es presentate un revista de 29 casos de glissage precoce del epiphyse femoral superior, tractate per fixation con un clavo de Smith-Petersen, sin reduction e con precoce permission de peso. Le resultatos esseva excellente, de accordo con le grado de glissage al tempore del tractamento. Le complicationes del fixation e le sequellas del condition es passate in revista e comparate con constatationes correspondente in le litteratura. Le admission precoce de peso—intra duo o tres septimanas—es possibile e mesmo desirabile, providite que nulle alteration in le stato del epiphyse glissate ha essite effectuate. Le incidentia de necrosis aseptic e de alteration arthritic es practicamente negligibile in iste typo de caso. Observationes subsequente in juveniles de bassissime etate al tempore del fixation demonstra que le increscentia del clavo, con perdita del fixation del epiphyse, non compromitte necessarimente le resultado. Isto resulta del replenation del canal clavo con nove histos de osso, con le effecto del formation de un graffo de osso vive a transverso le linea epiphysee. Le foration repetite del linea epiphysee al tempore del fixation initial resultarea probabilemente in un acceleration de iste processo e reducerea additionalmente le le risco de glissage tardive post increscentia del clavo. In general, nostre resultatos es satis simile al resultatos reportate in le litteratura pro simile series tractate per simile methodos. Isto indicate que le technica de tractamento hic describite es le technica de election in casos de glissage lente, precoce, o moderate.

16

Bilateral Anterior Fasciotomy for the Correction of Persistent Lordosis in Children

DUNCAN C. MCKEEVER, M.D.*

Fasciotomy of the iliotibial band has been recommended by Ober and others for the relief of low-back pain. I had occasion to see it carried out for this purpose in a large series of cases done with Doctors Dickson and Diveley in the middle 30's. In many patients a great deal of relief was afforded, but observation of these cases led me to the conclusion that, in most instances, this relief was afforded by the correction of persistent lordosis. Anatomically, the iliotibial band varies somewhat in its location in relation to the greater trochanter. It is described as being 70 per cent anterior to the trochanter, 20 per cent over the trochanter, and 10 per cent posterior to the trochanter in the standing position. In any location it must slide back and forth over the trochanter in normal locomotion.

At times the iliotibial band is so tight that it moves over the trochanter with difficulty, resulting in the condition known as *snapping hip*. This condition is easily relieved by fasciotomy.

Occasionally one sees a child in whom the normal infantile lordosis persists past infancy and well into adolescence. Most cases respond satisfactorily to corrective exercises; some, however, do not. If a supine child is able to flex his trunk to the erect position without the help of the psoas muscles, it should be possible for him to modify materially, and probably completely correct, his lordosis. If a child is able to do this exercise 50 times, and if he has persisted in the exercise for several months and the lordosis is uncorrected, some anatomic abnormality must be acting as a passive force to maintain this position. A few of these children will be found to have a very tight fascia lata with the iliotibial band anterior to the trochanter in the standing position. Tests for tension of the fascia lata are of little significance. The only observation that is of significance is the palpable tension in the fascia lata in the standing position. This can be felt by palpating the sides of the thighs just above the knees. In these cases the posture can be altered radically by an anterior fasciotomy. The procedure is as follows:

With the patient supine, the legs are crossed at the ankles with the leg to be operated upon first underneath. The patient then is draped, and a small incision is made running laterally and distally about 1½ inches from a point just below the anterosuperior spine of the ilium. It is possible to retract the skin edges so that a complete division of the fascia lata can be done. In these cases the extreme tension of the fascia lata can be felt by trying to pass a finger between the the greater trochanter and the iliotibial band. In many cases the band is so tight that this is impossible. The fascia lata is divided both under and over the tensor fascia femoris muscle. The fascia under

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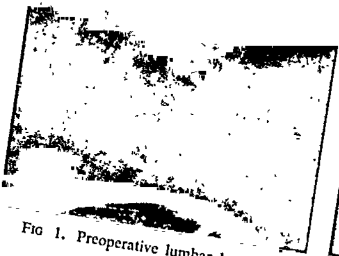

FIG 1. Preoperative lumbar lordosis

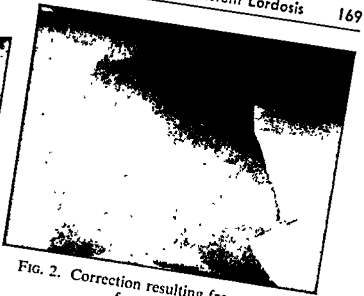

FIG. 2. Correction resulting from anterior fasciotomy.

the muscle usually is thicker. This division is carried back to a point just posterior to the trochanter.

All intermuscular septa and tense fascial structures anterior to the hip joint are divided. No muscle is divided. Hemostasis is secured. The incision is closed superficially, and a dressing is applied. The legs then are crossed, with the other leg underneath, and the same procedure is carried out on the opposite side. Figures 1 and 2 of such a case demonstrate the amount of release and the correction of lordosis obtained while the patient was still lying on the table. Figure 1 was taken before the operation; Figure 2, after it.

It is my opinion that this procedure should be carried out in children who fail to respond to postural correction and in selected adults who have a passively uncorrectable extreme lordosis.

Fasciotomia Anterior Bilateral pro le Correction de Persistente Lordosis in Infantes e Juveniles

Summario in Interlingua

Fasciotomia del tracto iliotibial ha essite recommendate per Ober e alteres pro alleviar dolor infero-dorsal. Illo frequentemente resulta in tal alleviamento in patientes in qui un tense fascia late es le causa de persistente lordosis. Le tracto iliotibial es describite anatomicamente como 70 pro cento anterior al trochanter, 20 pro cento supra le trochanter, e 10 pro cento posterior al trochanter in position erecte. In omne postura illo debe glissar in retro e in avante super le trochanter in locomotion normal. Sub certe conditiones le tracto iliotibial es si tense que illo glissa super le trochanter con difficultate solmente. Le resultato es le condition cognoscite como coxa a resorto. Iste condition es facile a alleviar per fasciotomia.

A vices le normal lordosis infantil persiste in ultra del infantia e usque al adolescentia o plus longemente. Certe tal casos non responde a exercitios corrective. Si nulle responsa es evocate per continue exercitios, le causa anatomic del persistente lordosis debe esser determinate. Si le tracto iliotibial es responsabile, illo es trovate anterior al trochanter (con le patiente in position erecte) e sub un tension considerabile que pote esser percipite quando on palpa le

coxas justo supra le genu, semper con le patiente in position erecte. In tal casos le postura pote esser alterate radicalmente per fasciotomia anterior.

Le processo operatori es le sequente: Le patiente se trova in decubito dorsal, con le gambas cruciate al cavilias. Le gamba que debe esser operate primo es placiate in supra. Un micre incision es effectuate justo infra le spina antero-superior del ilion. Per *retraction del pelle, un adequate fasciotomia* pote esser effectuate via un incision de non plus que un pollice e medie in longor. Le tension extreme del fascia late in tal casos pote esser demonstrate si on tenta inserer un digito inter le trochanter major e le tracto *iliotibial. Le operation continua per divider* le fascia late a ambe lateres del musculo tensori del fascia femoral retrorsemente usque a un puncto justo posterior al trochanter major. Omne le septos intermuscular e le tense structuras fascial anterior al articulation coxal es dividite. Nulle musculo es dividite. Hemostase es effectuate, e le incision es claudite superficialmente.

Alora le gambas es cruciate con le altere gamba in supra, e le mesme procedimento es effectuate al latere opposite. Le accompaniante illustrationes demonstra le grado de alleviamento obtenite e le correction del lordosis possibile durante que le patiente jace super le tabula.

In le opinion del autor, iste operation deberea esser interprendite in juveniles qui *non responde al correction postural* e in seligite adultos con passivemente incorrigibile lordosis de grado extreme.

17

The Carpal Tunnel Syndrome

RADFORD C. TANZER, M.D.*

The carpal tunnel syndrome, also called median neuritis or compression neuropathy of the median nerve at the wrist, is a disabling disease characterized by episodes of burning, aching pain involving one or both hands, intensified during the early morning hours, and responding dramatically to release of median nerve compression by division of the roof of the carpal canal.

In 1880 Putnam[14] collected 31 cases of nocturnal median nerve paresthesia; in 1913 Marie and Foix[10] described an autopsy presenting bilateral thenar atrophy associated with neuromata just proximal to the transverse carpal ligament. More recently, articles by Cannon and Love,[4] Brain, Wright and Wilkerson,[3] Kremer, Gilliatt, Golding and Wilson,[9] Phalen and Kendrick,[13] Tanzer[19] and others have cast light on the etiology of the disease and have established it as a clinical entity.

THE CLINICAL PICTURE

The hard-working middle-aged female seems to be particularly prone to develop symptoms, though a sudden change to more strenuous manual labor may precipitate attacks in either sex. More than half of the patients fall within 30 and 50 years of age. Bilateral involvement is noted more frequently in the so-called spontaneous type, in which no traumatic background is elicited, whereas cases with structural changes in the carpus or the base of the radius due to trauma are usually unilateral.

Numbness, and paresthesia described as a tingling, burning, prickling or painful sensation, are present in part or all of the median nerve distribution in the hand; they occur in almost all cases and occasionally radiate into the forearm. Sometimes there is a feeling of swelling or tightness in the affected fingers. Nocturnal pain, which is a prominent feature in most cases, usually appears several hours after the patient has retired, awakens him from sleep, progresses during the night and is relieved somewhat by allowing the hand to drop over the bedside or by shaking it. With morning activity symptoms usually diminish, but occasionally they will return when active use of the hand is resumed.

As the condition progresses, about half of the patients develop evidence of thenar muscle weakness. Skilled finger movements are lost, and objects are dropped inadvertently. Use of the hand becomes progressively limited until, eventually, the patient reaches a level of reduced manual activity at which he may function rather uncomfortably for years. Coldness of the fingers has not been a conspicuous feature in most reports, but it has been prominent in both Kendall's[7] and Tanzer's[19] series.

Objective findings are all explainable on the basis of median nerve compression within the carpal tunnel. Thenar atrophy may involve the abductor pollicis brevis, the flexor

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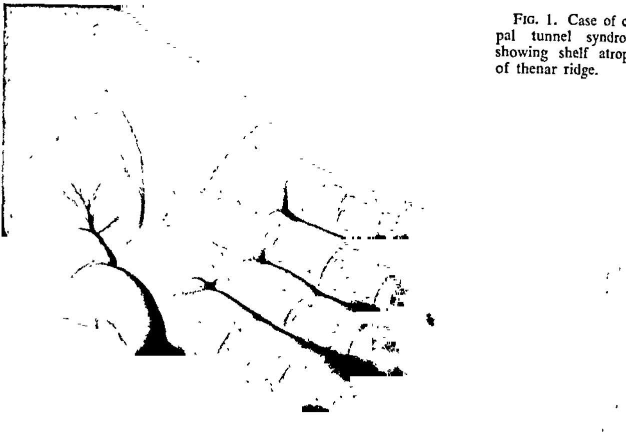

FIG. 1. Case of carpal tunnel syndrome showing shelf atrophy of thenar ridge.

pollicis brevis and the opponens muscles; when the two first muscles alone undergo wasting, the characteristic shelflike contour of the radial aspect of the thenar ridge appears (Fig. 1). Simpson[17] has carried out electromyographic studies of 15 cases of carpal tunnel syndrome and has demonstrated slowing of conduction of impulses applied to the median nerve at the wrist and picked up through electrodes placed in the abductor pollicis brevis and the opponens muscles. Repetitive firing of motor units after single shock stimulation appeared in 7 cases. The study is insufficient to warrant a quantitative appraisal, but he feels that the test may be helpful in evaluating doubtful cases. Conduction deficit in this disease has been confirmed by Stein.[18]

Clinical examination elicits evidence of sensory deficit in only half of the cases, a less frequent occurrence than one would surmise from the almost universal history of numbness. Hypesthesia, when present, is confined to the median nerve distribution, the middle finger being involved most frequently and persisting longer after surgical correction in this finger than in the others. Tinel's sign, consisting of a tingling sensation in the hand elicited by percussion of the median nerve at the level of the wrist, or carpus, is somewhat equivocal, Kremer *et al.*[9] having found it present infrequently, whereas Phalen and Kendrick[13] demonstrated its presence in 89 per cent of their cases. Tenderness may be produced by pressure over the carpal canal, or a mass may be palpable along the course of the nerve proximal to the ligament when the disease has progressed to the stage of pseudoneuroma.

Gilliatt and Wilson[5] have devised a tourniquet test that they consider to be valuable in diagnosing borderline cases. In normal circumstances, blocking of the circulation in the arm produces tingling either on the ulnar side or diffusely throughout the hand, but almost never solely in the median nerve distribution. In cases of carpal tunnel syndrome, a positive tourniquet test is evidenced by aching and paresthesia in the median nerve field; this occurs within 60 seconds of

application of pressure and spreads occasionally above the wrist, lasting 7 or 8 minutes and reproducing exactly the patient's nocturnal discomfort. In several subsequent reports by other authors this test has proved to be less conclusive.

Phalen and Kendrick[13] have described a "wrist-flexion" test that they have found to be a helpful diagnostic aid. Maintenance of acute flexion of both wrists for 60 seconds produces a prompt intensification of numbness and paresthesia in the median nerve distribution, with immediate relief or symptoms when the wrist is returned to a neutral position. They report the test as positive in 75 per cent of their patients.

Typical cases are not easily confused with other diseases, particularly when nerve compression is related to some demonstrable pathology such as an old carpal fracture or hypertrophic arthritis. However, when atypical symptomatology presents itself, particularly with upper-arm discomfort, one should consider three more common conditions, i.e., cervical arthritis, ruptured cervical intervertebral disk and scalenus syndrome, as well as the less likely possibilities of spinal cord tumor, syringomyelia, demyelination disease and polyneuritis. One must also bear in mind that compression neuropathy of the median nerve is not confined to the carpal tunnel itself. Bell and Goldner[2] and Kopell and Thompson[8] have described cases in which compression has been demonstrated in the palm of the hand, at the point at which the median nerve pierces the two heads of the pronator teres muscle and in the vicinity of the medial supracondylar ridge of the humerus.

PATHOLOGY

A glance at a cross section of the carpal canal demonstrates the vulnerability of the median nerve to pressure changes (Fig. 2). The carpal bones are tightly joined to form a trough transmitting the long flexor tendons of the hand and the median nerve. The trough is transformed into a canal by the transverse volar carpal ligament, a firm, unyielding structure attached principally to the pisiform and the hook of the hamate on one side and to the tubercle of the navicular and the crest of the greater multangular on the other. As viewed in cross section, the carpal canal is roughly triangular with rounded angles, the apex of the triangle being directed to the radial side and containing the flexor pollicis longus tendon. The median nerve lies in close apposition to this tendon on its volar and ulnar aspect, while the eight

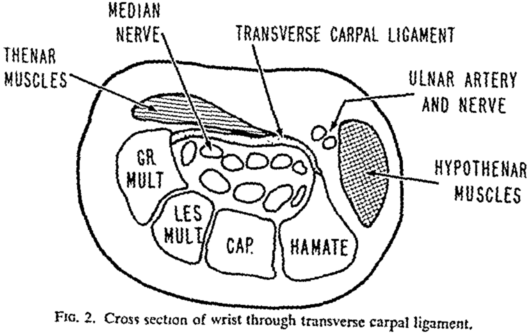

FIG. 2. Cross section of wrist through transverse carpal ligament.

flexor tendons of the fingers occupy the larger ulnar component of the tunnel. The median nerve is encased in a cellulo-adipose layer, fixing the nerve rather firmly to the walls of the tendinous bursa.[6]

It is in this region that changes can be demonstrated at operation. Varying degrees of nerve compression occur, but they are not necessarily proportional to the severity of symptoms. One of the earliest evidences of compression is a mild, segmental edema of the median nerve in the proximal third of the tunnel, sometimes combined with slight hyperemia of the perineural membranes (Fig. 3). More pronounced cases present an actual, well-localized constriction of the nerve, usually at the same level, and may or may not be combined with a pseudoneuroma (Fig. 4). The latter may consist of a fusiform swelling of the nerve just proximal to the proximal edge of the transverse carpal ligament, or it may be pear shaped, the larger component lying proximal to the canal while the smaller part tapers into its proximal third. When constriction of the nerve is pronounced, atrophy of the nerve distal to the constricted point is found and lends a poor prognosis so far as complete return of function is concerned.

Michaelis[12] described thickening and necrosis of the transverse carpal ligament in one case, a finding not reported by other authors. A careful comparison of measurements of the carpal ligament in cases of carpal tunnel syndrome and in routine autopsies has failed to reveal any significant variation in thickness between the two groups.[19] One sometimes notes diffuse adhesions of the investing perineural and peritendinous tissues that display a lack of their normal luster. In other cases one finds well-developed tenosynovitis with inflammation and edema of the bursal lining and an excessive accumulation of synovial fluid that occasionally may be identified by palpation as a tense, fluctuant tumor on the volar aspect of the wrist.

If the entire contents of the carpal canal

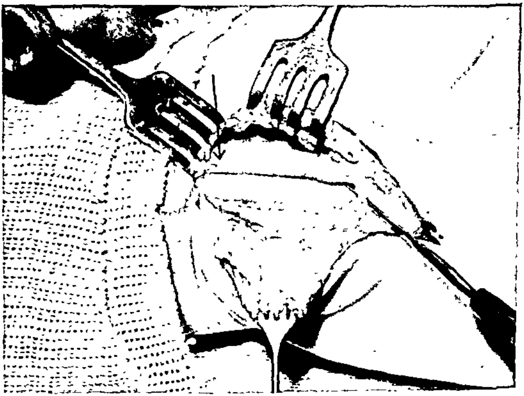

FIG 3. Mild type of carpal tunnel syndrome, showing edema of median nerve (indicated by arrow) and lack of normal luster of perineural membrane.

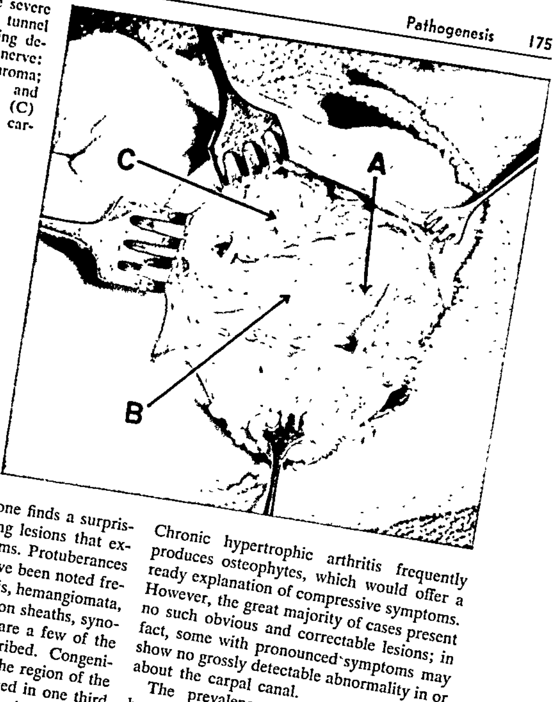

FIG. 4. More severe type of carpal tunnel syndrome, showing degeneration of nerve: (A) pseudoneuroma; (B) constriction and atrophy of nerve; (C) divided transverse carpal ligament.

are examined routinely, one finds a surprising number of space-filling lesions that explain compressive symptoms. Protuberances about old fracture sites have been noted frequently. Arterial thrombosis, hemangiomata, amyloid disease of the tendon sheaths, synovial cysts and gouty tophi are a few of the lesions that have been described. Congenital anomalies in and about the region of the carpal canal, which were noted in one third of the author's series,[19] may play a part in producing nerve compression.

PATHOGENESIS

The etiology of this seemingly rather clear-cut syndrome is surprisingly obscure. It is probable that the disease can be precipitated by several inciting factors. For instance, in the original report of Cannon and Love,[4] 8 of their 38 cases were associated with prior fractures about the wrist, or carpus, with roentgenologic evidence of compression of the contents of the canal by bone.

Chronic hypertrophic arthritis frequently produces osteophytes, which would offer a ready explanation of compressive symptoms. However, the great majority of cases present no such obvious and correctable lesions; in fact, some with pronounced symptoms may show no grossly detectable abnormality in or about the carpal canal.

The prevalence of the disease among housewives at or near the time of the menopause supports the hypothesis that some physiologic change may render the nerve susceptible to compression at this particular time of life. Woltman[20] and Schiller and Kolb[16] have directed attention to its association with acromegaly and to improvement in symptoms after radiation or extirpation of the pituitary tumor. Reid[15] has treated the so-called spontaneous type with Stilbestrol with at least temporary improvement, which suggests to him that there is a hormonal mediation of fluid distribution in the soft tissues of the wrist that is correctable, at least

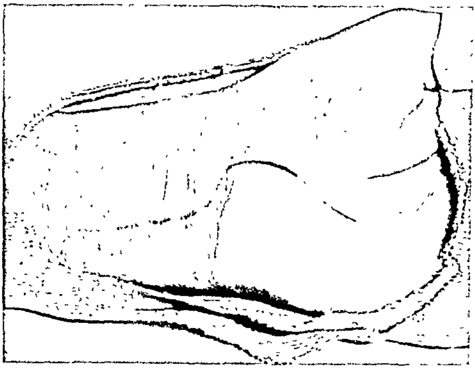

FIG. 5. Solid line represents initial incision for exposure of carpal canal. Extension along broken line will permit further exposure of median nerve if indicated.

to some degree, by administration of estrogens.

Phalen and Kendrick[13] have concluded that spontaneous compression of the median nerve is caused by thickening of the flexor synovialis within the carpal tunnel, as borne out by microscopic studies that revealed chronic inflammation consistent with rheumatoid synovitis in one third of their cases and a nonspecific fibrosis in the remainder. In our earlier studies we also were under the impression that fibrosis of the bursal membranes was almost always present, but a subsequent study of the carpal canal in a series of unselected autopsies[10] has led us to the conclusion that mild degrees of fibrosis are a common finding in any carpal tunnel.

Many observers feel that the inciting factor in spontaneous nerve compression is the assumption of unaccustomed manual work Brain and his co-workers[3] are convinced that extension of the wrist is the significant motion, and they have carried out experiments involving the insertion of tambours in the carpal tunnels of cadavers that seem to indicate that intraluminal pressure is increased threefold by wrist extension. They suggest that vascular degeneration in middle life increases the ischemic effect upon the nerve of pressure that would be harmless in younger individuals. Kendall,[7] in a careful study of the carpal canal, concurs with Brain that dorsiflexion of the wrist is the significant inciting motion and explains the compression on the basis of muscle action. He notes that constriction of the contents of the canal occurs when tension is exerted on the long digital flexors with the wrist held in dorsiflexion. This compression is increased supposedly by contraction of the wrist flexors if the wrist is held in extension. Abbott and Saunders,[1] on the other hand, have demonstrated that solutions of Berlin blue and Lipiodol can be passed easily down the median nerve sheath when the wrist is held in extension, but that an injection of the liquid medium is blocked by acute flexion of the wrist. Meadoff[11] has obtained similar results by attempting to pass Lipiodol from the forearm to the hand through the carpal canal.

One factor that has failed to command the attention of virtually all writers dealing with the clinical aspects of this subject is the compressive effect on the median nerve produced

by simultaneous and forceful flexion of the wrist and the fingers. This observation is based on a simple anatomic concept: when the fingers are flexed with the wrist in extension, the flexor tendons are squeezed against the posterior wall of the carpal tunnel; on the other hand, flexion of the fingers with the wrist flexed compresses the median nerve between the tight flexor tendons within the canal and the transverse carpal ligament with a force proportional to the degree of grasp exerted by the digits. A review of our own cases, as well as the reports of others, has impressed us with the frequency with which one obtains an antecedent history of change to a new occupation or avocation in wl repeated forceful flexion of the fingers v the wrist in a neutral or a flexed posi played an important role.[10]

TREATMENT

The treatment of carpal tunnel syndr is clear cut. In mild cases, symptoms r be alleviated by having the patient ref from inciting types of manual exercis such curtailment of activity can be d without prejudice to occupation or av tion. Splinting usually will give tempo relief from the more acute symptoms, but sumption of activity is apt to reproduce th

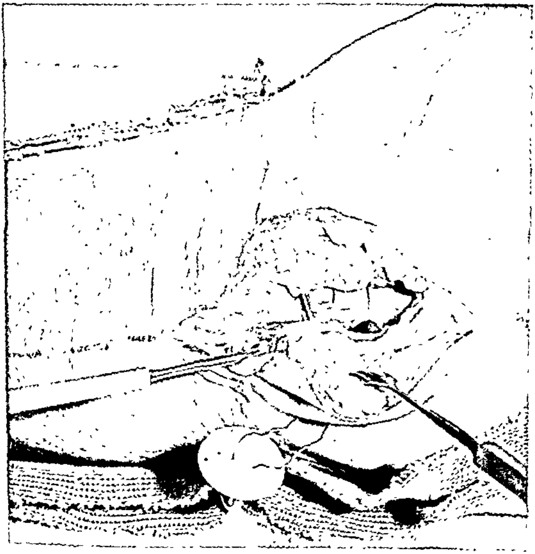

FIG. 6. After completion of exploration of carpal tunnel, divided transverse carpal ligament is closed partially over contents of carpal canal by a wire mattress suture brought out onto the ulnar side of the hypothenar eminence. Nerve hook elevates ulnar neurovascular bundle.

promptly. Extended conservative treatment is not acceptable when a simple operative procedure entailing only a few days of convalescence will afford prompt relief.

Division of the transverse carpal ligament will give permanent relief of symptoms and will restore median nerve function except when irreversible damage has occurred. Hypesthesia is always improved, but in the more severe cases it persists in some areas, the tip of the middle finger being involved most frequently. Motor weakness responds less dramatically to release of nerve compression since its presence usually denotes significant nerve damage. Earlier writers recommended blind division of the ligament, introducing a blunt-tipped knife through a transverse incision at the wrist and dividing the ligament along its ulnar aspect in order to avoid damage to the median nerve and its branches. This method failed at times to give relief, due to incomplete severance of the ligament, and also it failed to cast light on any pathologic conditions present in the carpal tunnel.

It is conceded generally now that the division of the transverse carpal ligament under direct vision is the procedure of choice. The approach that we have found to be most satisfactory (Fig. 5) is a gently curving longitudinal incision that starts at the level of the distal rim of the carpal ligament, extends longitudinally along the base of the hypothenar eminence to the center of the wrist, and then swings transversely to the ulnar side between the proximal and the distal volar wrist creases for about 2 cm. If further exploration of the median nerve is desired, the incision then can be extended farther into the forearm along its volar and ulnar aspect. The palmar cutaneous branches of the median and the ulnar nerves often are not identified, but they should be preserved if possible. The ulnar neurovascular bundle is retracted, the ligament is divided along its ulnar side, and the contents of the canal are inspected. It is important to expose the floor of the canal, as occasionally the cause of nerve compression will be revealed at this level.

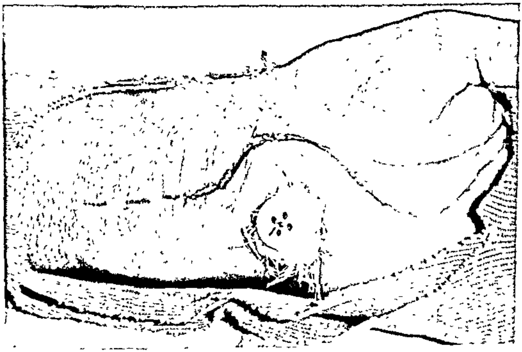

FIG 7 Mattress suture is tightened over a padded button. Wound is closed subsequently with a single layer of skin sutures

Closure of the ligament is neither possible nor desirable, but we have found it to be advantageous to place a 32-gauge stainless-steel wire mattress suture through the longer flange of the divided ligament and bring it either superficial or deep to the ulnar neurovascular bundle onto the side of the hypothenar eminence, where it is tied snugly over a padded button, thus retaining the ligament in a flattened position over the contents of the carpal canal (Figs. 6 & 7). The wound is closed by a single row of skin sutures, and plaster splinting of the wrist is maintained for 1 week.

Occasionally, some stiffness and tenderness about the wrist incision is noted for 3 or 4 weeks, but usually the dramatic relief of pain and paresthesia is apparent immediately after operation, and, as virtually all authors agree, relief is permanent.

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Le Syndrome del Tunnel Carpal

Summario in Interlingua

Le syndrome del tunnel carpal es un recentemente recognoscite entitate, characterisate per episodios nocturne de un sensation de arditura, disconforto dolorose in le mano e antebracio, e torpor e paresthesia in le portion del mano que es servite per le nervo median. Illo occurre le plus frequentemente in femininas de etate medie e pote supervenir spontaneemente o como resultato tardive de trauma in le region del carpo. Le constatationes objective include atrophia del musculo thenar, hypoesthesia del pollice e del tres digitos adjacente, positivitate del signo de Tinel, e—incerte casos—manifestationes de vasospasmos. Arthritis cervical, ruptura de disco intervertebral, e syndrome de scaleno debe esser prendite in consideration in les diagnose differential.

Le exploration del tunnel carpal revela usualmente signos de compression del nervo median. Le tertio proximal del canal es le sito usual del compression. Isto pote esser characterisate per edema del nervo o, in le plus avantiate casos, per un definite constriction del nervo, con o sin pseudoneuroma associate. Le inspection complete del canal pote revelar le presentia de tenosynovitis o de varie lesiones a formation de massa que es responsabile pro le symptomas de compression.

In multe casos le etiologia remane obscur. Factores que possibilemente exerce un influentia es alterationes physiologic in le carpo del typo associate con le menopause, le stato rheumatoide, anomalias congenite, e lesiones post-traumatic. Plure autores ha sublineate le importantia de un inaccostumate activitate manual como factores instigatori in le spontanee compression de nervos. Un conflicto de opiniones existe con respecto al typo de movimento manual que precipita le symptomas. Datos ha essite citate in supporto tanto de flexion como etiam de extension carpal como possibile factor precipitatori in le production del compression de nervos.

Le division del transverse ligamento carpal resulta in le complete alleviation del symptomas, excepte in le presentia de irreparabile damnification del nervo median. Accesso directe al ligamento debe esser preferite al division cec per un incision carpal. In le accesso directe le resultato es plus certe, e le methodo provide le opportunitate de explorar le complete tunnel carpal.

18

Fracture-Dislocations of the Wrist

CARRUTH J. WAGNER, M.D.*

Fractures and fracture-dislocations about the wrist as a group constitute a very common injury. Because of the importance of the hand in everyday life and the intricate function of the carpus, these injuries deserve considerable study and discussion if the best methods of treatment are to be developed.

Although most injuries to the wrist are the result of a fall on the outstretched hand, the exact mechanism of injury seldom can be determined. The manifestations in the individual case will depend on the direction and the power of the deforming force, anatomic differences in the various carpal bones, and the state of the ligamentous structures and of the muscles when the injury was sustained. However, most injuries follow a rather definite sequential pattern, and it is only through an understanding of this pattern that one can truly evaluate the extent of the injury and the prognosis in the individual case.

ANATOMIC FEATURES

Anatomically, the carpus is composed of 8 carpal bones arranged in a proximal and a distal row. Functionally, the lunate and the triangular act as a unit in the proximal row; not infrequently they are fused to form a single bone. The pisiform is a sesamoid that conducts the flexor carpi ulnaris to the distal carpus.

The lesser multangular, the capitate and the hamate act as a unit in the distal row. The navicular functions as a connecting rod between the 2 rows; its proximal pole functions with the lunate and its distal pole with

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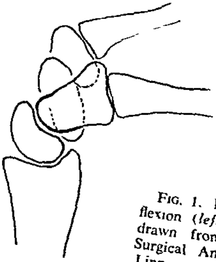

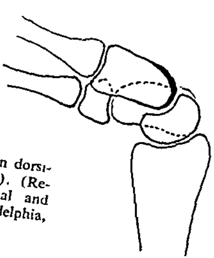

FIG. 1. Relationship of carpal bones in dorsiflexion (*left*) and palmar flexion (*right*). (Redrawn from Kaplan, E. B.: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott)

the capitate. The naviculo-capitate attachment is considerably stronger than the naviculo-lunate attachment.

The greater multangular, developmentally and functionally, is a modified thumb-ray metacarpal.

Normally, most of the volar flexion of the hand takes place in the radiocarpal joint and, to a lesser extent, in the mid-carpal joint. Dorsal flexion is provided primarily by the mid-carpal joint, the radiocarpal joint contributing only slightly to the movement. (Fig. 1)

Radial inclination or flexion of the hand occurs primarily in the mid-carpal joint, and the navicular angulates volarward to avoid the radial styloid.[1] Ulnar inclination or flexion is primarily a function of the radiocarpal joint. (Fig. 2)

The function of the radiocarpal joint is relatively simple as an ellipsoidal joint, but the mid-carpal joint is more complex since it acts differently on the radial and the ulnar sides of the mid-axial line. The radial portion of the mid-carpal joint is represented by the distal half of the navicular, the greater and the lesser multanguli rotating about the radial aspect of the capitate; there is a slight gliding movement in the lateral and the medial portions of the joint.

The ulnar portion of the mid-carpal joint, consisting of the lunate, the proximal pole of the navicular, the hamate and the triangular, acts as a multi-axial diarthrodial joint about the distal ulnar surface of the capitate.

The capitate is fixed firmly to the third metacarpal, through which the long axis of the hand progresses into the carpus. The ligamentous attachments of the various carpal bones are so arranged that the lesser multangular, the distal pole of the navicular, the capitate, the hamate and the triangular form a close-knit group attached firmly to the metacarpals, while the lunate and the proximal pole of the navicular represent a separate unit in contact with the radius.

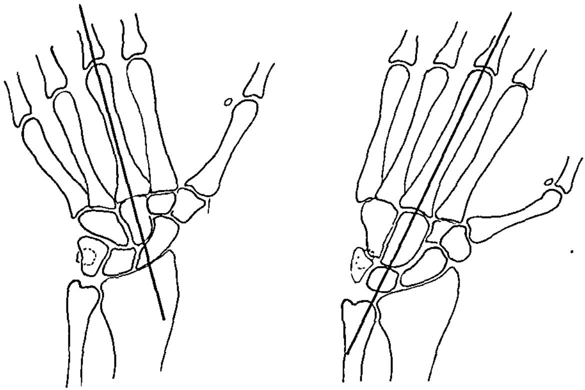

Fig. 2 Relationship of carpal bones on ulnar (*left*) and radial (*right*) flexion of the wrist. (Redrawn from Kaplan, E. B.: Functional and Surgical Anatomy of the Hand, Philadelphia, Lippincott)

FIG. 3. (*Left*) Fracture of the radius with incomplete displacement. (*Right*) Fracture of the wrist with complete displacement and dislocation of the radio-ulnar joint.

In summary, the salient anatomic points that are important in determining the various fracture-dislocations occurring about the wrist may be listed as follows:

1. The capitate is fixed firmly to the third metacarpal and always moves with the hand.
2. The lunate is relatively fixed to the radius.
3. The capitate-lunate joint acts as the junction of the fixed axis of the hand and the forearm.
4. The navicular acts as a connecting rod bridging the mid-carpal joint, with its distal pole intimately attached to the capitate and its proximal pole less intimately attached to the lunate.
5. The ligaments of the wrist joint are so distributed as to permit motion of the individual joints and at the same time enable the carpus to act as a unit.

SEQUENTIAL PATTERN OF INJURY

With the above anatomic factors in mind, one can reconstruct rather closely the mechanism of injury in each case of fracture-dislocation of the wrist.

When a fall is arrested by the outstretched hand, usually the wrist dorsiflexes. If the force exceeds the range of motion naturally permitted by the various ligaments, generally the distal radius gives way, resulting in the typical Colles fracture (Fig. 3, *left*). The degree of displacement depends on the summation of the forces producing the fracture (Fig. 3, *right*).

Occasionally, the lunate is buttressed by the dorsal lip of the radius, and, before the latter gives way, the navicular fractures at the waist (Fig. 4, *top*). This occurs not because it is compressed against the styloid of the radius but because the dorsal lip of the radius holds the lunate in position long enough for the capitate to exceed the normal range of dorsiflexion in the capitate-lunate joint. When this takes place, the navicular, being closely applied to the capitate at its distal pole and to the lunate at its proximal pole, must either fracture or sever its rela-

tionship with one or the other and dislocate (Fig. 5).

When the navicular fractures, the fragments do not displace if the force ends or is dissipated by the radius fracturing. Thus, an anatomic relationship of the fractured navicular is the rule when it accompanies a Colles fracture (Fig. 4).

When the dorsal radius remains intact, the force applied to the outstretched hand may be expended in a simple fracture of the navicular (Fig. 6). If, however, the force continues, the capitate may escape the lunate, and the typical perilunar transnavicular dislocation results (Fig. 7). The capitate, the hamate, the triangular, the lesser multangular and the distal fragment of the navicular remain in normal relationship to each other *and dislocate dorsally, while the lunate, together* with the proximal pole of the navicular, maintains a normal relationship with the radius.

If the navicular fails to fracture, it must sever its relationship with the lunate and accompany the capitate or remain behind with the lunate. Since its attachments to the capitate are the stronger of the two, the former is what usually happens (Fig. 8).

Isolated dislocations of the navicular have been reported,[8,10] but careful examination usually reveals that there is a loss of normal relationship of the capitate-lunate joints, indicating that these cases are really perilunar dislocations. Even when the relationship at this joint appears to be normal, careful observation at the time of reduction reveals that

FIG. 4 Colles' fracture with fracture of the carpal navicular. (Anteroposterior and lateral views)

the joint subluxates with ease with slight traction, and, in fact, the perilunar dislocation must be reproduced in order to permit the return of the proximal pole of the navicular (Fig. 9).

If the force continues after dislocation of the capitate-lunate joint, the carpus usually bypasses the lunate and may be pushed proximally to the level of the articular surface of the radius (Fig. 10, *left & right*). As this occurs, the lunate flexes progressively and ultimately may dislocate, allowing the carpus to assume a relatively normal relationship to the radius (Fig. 11). In cases of apparent isolated dislocation of the lunate, the perilunar dislocation usually can be demon-

FIG. 5. Dislocation, carpal navicular.

FIG 6. Fracture, carpal navicular, without displacement.

FIG. 7. Perilunar transnavicular dislocation.

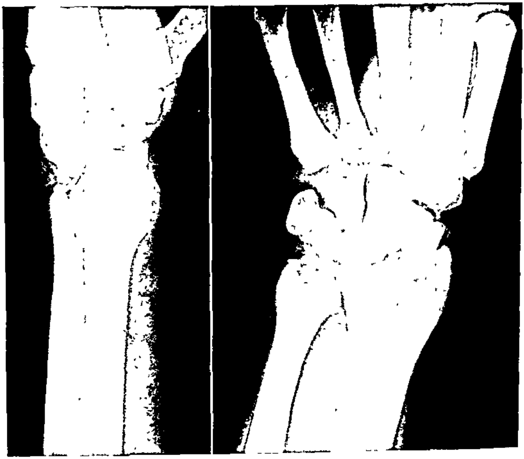

FIG. 8 Perilunar dislocation without fracture of the navicular.

strated at the time of reduction. When the wrist is brought into dorsiflexion, the carpus can be felt to dislocate dorsally, with spontaneous reduction of the lunate. With traction and palmar flexion the perilunar dislocation then may be reduced.

When the perilunar dislocation occurs without fracture of the navicular, the radial

and the ulnar styloid processes usually are fractured (Fig. 12). These are of the avulsion rather than the compression type.

Variations in the force of injury and the position of the extremity may result in complete dislocation of the carpus dorsally. This may occur with fracture of the dorsal lip of the radius (Fig. 13) or without fracture of the radius (Fig. 14).

Rarely, the perilunar dislocation occurs to the volar aspect of the extremity rather than dorsally (Fig. 15). Occasionally, isolated fractures of the greater multangular may be seen (Fig. 16) and are the result of direct trauma to the thumb ray. Fractures of the triangular are relatively common and usually represent an avulsion from the dorsal surface (Fig. 17). Occasionally, however, the triangular comminutes and is associated with dislocations of the pisiform (Fig. 18). In these cases careful examination is necessary for early recognition of injury to the deep motor branch of the ulnar nerve.

TREATMENT

In the treatment of the fracture and the fracture-dislocation of the wrist, the reduction usually can be accomplished by closed methods with little difficulty. However, the physician must be prepared to spend much time and anticipate considerable disability as the result of complications that commonly accompany this type of injury. Since many of the dislocations are reduced by the patient before he is seen by the physician or the roentgenologist, there is a tendency to underdiagnose these injuries. This further complicates the prognosis. The following observations may supplement the many texts and articles available that deal with the treatment technic now being used.

COLLES' FRACTURES

Closed reduction will be improved and the reduction maintained better if the forearm is fixed in full pronation and the cast is extended above the elbow for the first 4 to 6 weeks. The normal volar inclination of the radius can be restored and the normal styloid

FIG. 9. Reduction of dislocated navicular usually demonstrates underlying perilunar dislocation. (See text.)

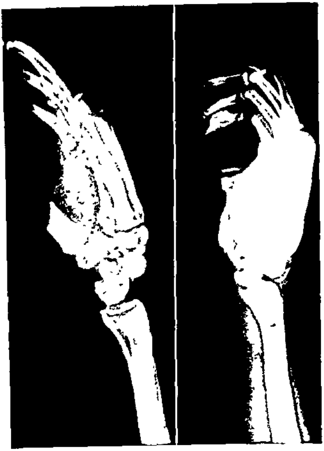

FIG. 10. Progression of perilunar dislocation with ultimate volar subluxation of the lunate.

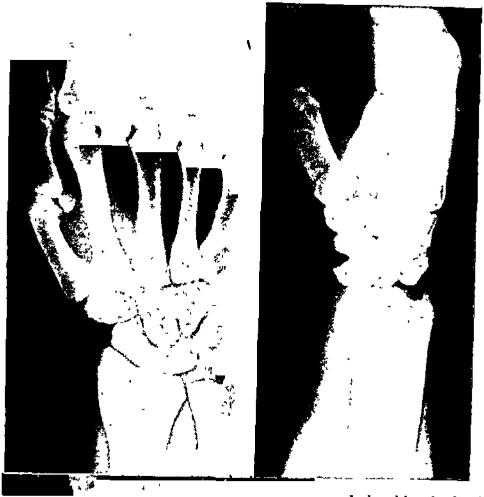

FIG. 11. As lunate dislocates, remaining carpus assumes a relatively normal relationship with the radius, leading to a misdiagnosis of isolated dislocation of the lunate (Wagner, C. J.: J. Bone & Joint Surg. 38-A: 1198-1207)

relationship obtained without palmar flexion if the position of full pronation is obtained and maintained during the early period of immobilization.

PERILUNAR DISLOCATIONS

If the principle that the usual fracture, dislocation and fracture-dislocation of the carpus have as a common denominator a dislocation or a potential dislocation of the capitate-lunate joint is accepted, considerable difficulty in the treatment of wrist injuries will be avoided. The treatment and the prognosis must be determined for each case

The initial reduction usually offers little difficulty (even dislocations several days old will reduce with surprising ease). When the navicular is not fractured, the reduction should be maintained with plaster, with the wrist in a position of function, the thumb

FIG. 12. Perilunar dislocation with fracture of the radial and the ulnar styloid processes (Wagner, C. J . J. Bone & Joint *Surg. 38-A:1198-1207)*

and the elbow free, for a period of 3 weeks. Then graduated exercises may be instituted and immobilization discarded over the next 2 weeks. The results usually are good, with only slight residual stiffness as a sequela.

When the navicular is fractured and is reduced anatomically when first examined, it is quite likely that the disrupting force was dissipated before significant damage to the ligamentous attachments occurred. Therefore, the blood supply to the proximal fragment remains intact, and, with immobilization, union can be predicted in a relatively short time with uniformly good results. Cylinder plaster is used, incorporating the proximal phalanx of the thumb with the wrist in a position of function, thumb in opposition and elbow free. Immobilization is maintained until there is roentgenographic evidence of union.

The slightest displacement of the navicular fragments should raise a suspicion that a perilunar dislocation has occurred. In this case the prognosis is entirely different. The

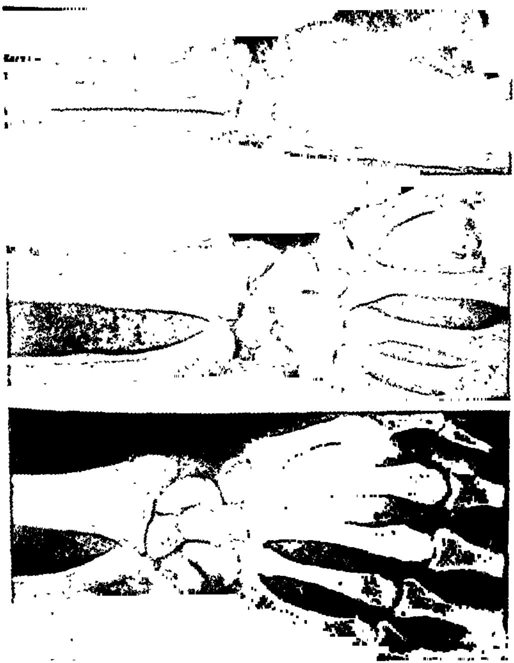

FIG. 13 Dislocation of carpus dorsally with fracture of the radius.

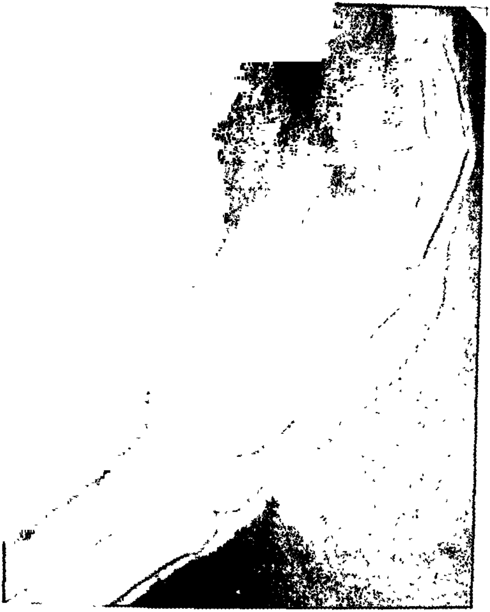

FIG. 15. Volar perilunar dislocation of the wrist.

navicular when an anatomic reduction cannot be obtained by closed methods. Thereby the period of disability and suffering is shortened, and such complications as reflex hyperemic deossification, permanent finger stiffness and shoulder involvement are largely avoided.

In performing an arthrodesis on an unreduced perilunar dislocation, care must be taken to align the carpus accurately, particularly the capitate-lunate joint. If the lunate is overlooked and left in a flexed position, the operation usually releases the dorsal lunate ligament, resulting in volar subluxation of the lunate, and postoperative median nerve compression symptoms may result.

Failure to obtain an anatomic reduction by closed methods when the navicular is not fractured necessitates open reduction. Here there is little danger of aseptic necrosis of the navicular, and the re-establishment of a normal intercarpal relationship results in a stable, useful wrist. Some motion is lost, and a traumatic arthritis commonly results, particularly between the lunate and the navicular.

In performing open reduction, a dorsal approach is used, and the radial and the ulnar borders of the lunate are defined, care being taken to preserve intact the dorsal radial lunate portion of the capsule. By gentle manipulation, the wrist is "set up" about the lunate. Accurate reduction is verified by the return of the proximal navicular pole and

incidence of aseptic necrosis with accurate reduction of the navicular is 50 per cent, and without accurate reduction it approaches 100 per cent.[11]

When aseptic necrosis intervenes, fairly *good results will be obtained with prolonged* immobilization if the reduction is accurate (Figs. 19 & 20). As may be seen in Figure 19, aseptic necrosis of the proximal fragment is present. Seven months later, with continuous immobilization, the fracture has united, and approximately two thirds of the proximal fragment has been replaced by creeping substitution. Immobilization must be continued until the entire proximal fragment is regenerated, or collapse and carpal *disintegration will occur (Fig. 21).*

When displacement of the navicular fragments persists, it indicates that the perilunar dislocation has not been reduced completely and that not only will aseptic necrosis intervene (Fig. 22) but progressive collapse of the fragment will permit the migration of the capitate to occupy the space between the lunate and the distal fragment (Fig. 21). The result is a painful wrist that resists all *forms of conservative treatment, and arthrodesis* becomes necessary.

Removal of the proximal fragment is useless and merely hastens the disintegration of the carpus.[11] In the author's experience, open reduction and fixation of the fractured navicular, when displaced, have yielded uniformly poor results. Aseptic necrosis of the navicular fragment usually has occurred and, due to the extensive ligamentous stripping necessary to gain normal capitate-lunate-triangular *relationship, leads frequently to a* fibrous ankylosis.[12]

It is the author's practice to recommend arthrodesis of the wrist at once in all cases of perilunar dislocation with fracture of the

FIG 14 Dislocation of carpus dorsally without fracture of the radius. (Wagner, C. J.: J. Bone & Joint Surg. 38-A:1198-1207)

FIG. 15. Volar perilunar dislocation of the wrist.

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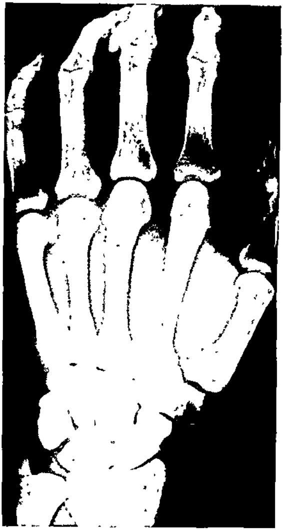

FIG. 16 Fracture, greater multangular.

FIG. 17. Avulsion fracture, triangular.

the triangular to the radial and the ulnar aspects of the lunate. In this way, reduction can be obtained with a minimum of ligamentous stripping.

When the lunate is dislocated, and there is no associated fracture of the navicular, closed reduction produces good results. With open reduction, the incidence of aseptic necrosis is very high. Removal of the lunate is *unsatisfactory, for it results in a much weak*ened wrist and permits disruption of the carpus due to the wedgelike action of the capitate.[12] Replacement with a prosthesis may be of value[6] Prolonged immobilization will *permit revascularization* and a fairly reasonable result, but it represents a very long investment in time (1½ years) (Fig. 23, *left*).

Rarely, the lunate and the proximal navicular both undergo aseptic necrosis (Fig. 23, *right*). Revascularization will occur with prolonged immobilization, but the stiffness and the associated arthritic changes result in a poor functional wrist. Early arthrodesis usually provides the most satisfactory form of treatment.

OTHER FEATURES

Fractures of the triangular are avulsion fractures as a rule, and, although the injuries appear to be insignificant, disability often is

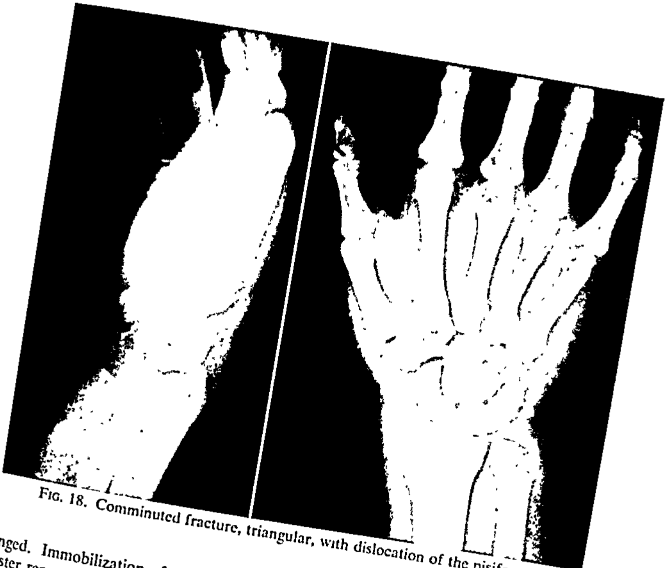

FIG. 18. Comminuted fracture, triangular, with dislocation of the pisiform.

prolonged. Immobilization of 4 to 6 weeks in plaster represents a good investment, for, although union of the avulsed fragments occurs in only one fourth of the cases, ligamentous ossification is minimized, and a good functional result occurs. Use of local heat and physical therapy without immobilization often results in a hyperemic deossification.

Comminuted fractures of the greater multangular usually involve the carpometacarpal joint. As a result, prolonged stiffness and pain in the use of the thumb commonly occur. In the treatment of this complication, excision of the greater multangular has been used with good results; however, the treatment of choice remains arthrodesis of the first metacarpocarpal joint.

Fractures of the other bones of the carpus are rare and present little difficulty in treatment. Rarely, in fractures of the hook of the hamate (as in fractures of the pisiform) the deep motor branch of the ulnar nerve may be injured. Careful examination (as

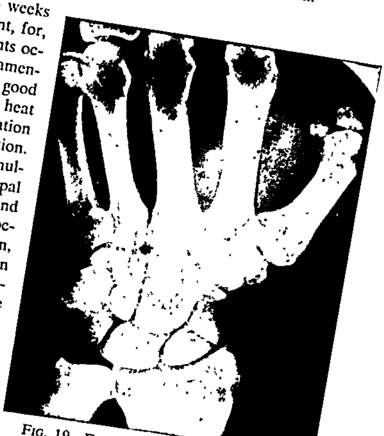

FIG. 19. Fracture, carpal navicular, with aseptic necrosis, proximal fragment.

FIG. 20. Progressive replacement of proximal fragment by creeping substitution under treatment by prolonged immobilization Union of the fracture occurs relatively quickly, but immobilization must be continued until revascularization of the proximal fragment is complete.

FIG 21. Collapse of aseptic necrotic proximal fragment with early mobilization. (Wagner, C. J.: J. Bone & Joint Surg. 34-A:774-784)

well as awareness of the danger) is necessary to avoid missing the diagnosis in these cases. When the nerve is involved, surgical exploration usually is indicated.

SUMMARY

Fractures and fracture-dislocations of the carpus follow a sequential pattern. In most cases there is a primary loss of relationship at the junction of the fixed axis of the hand with the forearm (the capitate-lunate joint), resulting in a perilunar dislocation of the wrist.

Manifestations of the basic perilunar dislocation will vary in individual cases, depending on the direction and the power of the deforming force, the anatomic differences in the various carpal bones, the ligamentous structures, and the state of the muscle balance when the injury occurred.

The prognosis in the individual case is predicted by the presence and the extent of associated fractures, particularly the navicular, the accuracy of reduction, and the use of closed methods of reduction.

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FIG. 22. Perilunar transnavicular dislocation that is incompletely reduced is associated with a very high incidence of aseptic necrosis. (Wagner, C. J.: J. Bone & Joint Surg. 38-A:1198-1207)

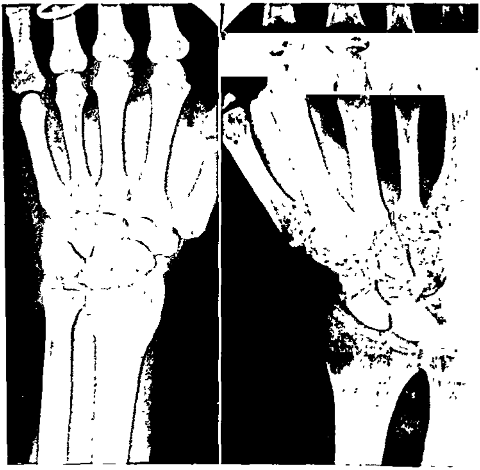

FIG 23 (*Left*) Result of treatment of aseptic necrosis of the lunate by prolonged immobilization. Good function in spite of residual deformity. (*Right*) Aseptic necrosis of lunate and proximal fragment of the navicular after perilunar transnavicular dislocation of the wrist, a rare complication.

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8. Russell, T. B.: Inter-carpal dislocations and fracture-dislocations; review of 59 cases, J. Bone & Joint Surg. 31-B:524-531, 1949.
9. Stack, J. K.: End results of excision of the carpal bones, Arch. Surg. 57:245-251, 1948.
10. Vaughan-Jackson, O. J.: A case of recurrent subluxation of the carpal scaphoid, J. Bone & Joint Surg. 31-B:532-533, 1949.
11. Wagner, C. J.: Fractures of the carpal navicular, J. Bone & Joint Surg. 34-A:774-784, 1952.
12. ———: Perilunar dislocations, J. Bone & Joint Surg. 38-A:1198-1207, 1956.
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Fracturas con Dislocation del Carpo

Summario in Interlingua

Fractura del carpo e fracturas con dislocation del carpo es characterisate per un sequentia de eventos interdependente. In le majoritate del casos il occurre un perdita primari del relationes normal al junction del axe fixe del mano con le antebracio (i.e. in le articulation de capitato e lunato), con le resultato de un dislocation perilunar del carpo.

Le manifestationes del basic dislocation perilunar varia in le casos individual. Illos depende del direction e del magnitude del fortia de deformation, del differentias anatomic inter le varie ossos carpal, del character del structuras ligamentose, e del stato del balancia muscular al momento del traumatisation.

Le prognose in le caso individual es determinate per le presentia e le grado de fracturas associate, specialmente in le osso navicular, per le accuratia del reduction, e per le uso de methodos de reduction claudite.

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19

The No-Name and No-Fame Bursa

FRED L. STUTTLE, M.D.*

The patients who, out of gratitude, have caused more other individuals to see me have been afflicted with a clinical bursitis of the knee for which I can find no positive name. I see at least one such patient per week. Yet I learn from colleagues that some have never seen such a patient or no more than one or two in their lifetime.

The clinical variance in many diagnoses, let alone treatment, in office orthopaedics is amazing. Voshell† has described 10 clinical cases of bursae that he found in four different locations under the mediotibial collateral ligament. The one that I encounter particularly is specifically right and exactly at the front edge of the superficial and parallel anterior fibers of the mediotibial collateral ligament. Voshell describes this as a "bursitis of a bursa under the mediotibial collateral ligament " I believe that this bursa is at times under the ligament, but, as the knee is bent, the bursa retains partial allegiance to the medial meniscus and slides forward with the meniscus during flexion. Since the anterior edge of the ligament moves backward in knee flexion, the ligament edge lies posterior to the bursa in this circumstance. Frequently, an enlargement and an irritation of this area can be felt as a small tender rounded nodule with ligament edge "jumping" onto it, and with pain, as on external rotation. This will occur, then, on attempting sharp extension of the knee and especially on external rotation of the flexed knee.

As will be seen in Figure 1, the handle of the knife is located under the ligament exactly at the joint line. DePalma‡ says, "The anterior portion of the superficial layer [of ligament] is attached loosely to the underlying meniscus. Frequently [94% of cases], a bursa is interposed between the two structures." However, in a later illustration (our Fig. 2), in more or less direct connection with this discussion, he shows a bursa definitely below the joint line and under this ligament. If there is a bursa here, it is not my especial friend. This also shows the rearward slide of anterior ligament edge in flexion. I do not believe, then, that the phrase *medial subligamentous,* which I have heard applied, is correct, since I do not regard the bursa as being subligamentous—at least in some portions of flexion of the knee. What I am saying is that, in my experience, this is a relatively common condition, and the interpretation has to be mainly clinical. In looking over texts on office practice of orthopaedics, journals and monographs on important bursitides of the knee, several well-known varieties are discussed. Baker has his cyst, even if quite variable as to location and significance as to cause and effect. The housemaid has her prepatellar. Several others are named and mentioned. In my experience this bursa without a name is both more common and therapeutically more important as a bursitis than any of those usually discussed. I should like to accord it much higher rank.

Ailments of this bursa present all grades

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* Peoria, Ill.

† Voshell, A. F., and Brantigan, O C.. Bursitis in the region of the tibial collateral ligament, J. Bone & Joint Surg. 26:783-793, 1944

‡ DePalma, A F.: Diseases of the Knee, p. 50, Philadelphia, Lippincott, 1954.

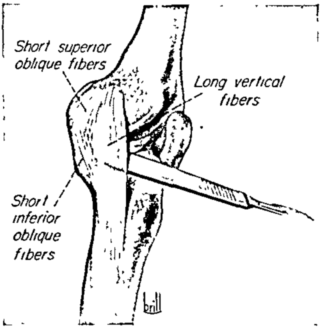

FIG. 1. Drawing of an anatomic dissection showing the interval between the anterior vertical border of the tibial collateral ligament and the medial meniscus. (DePalma, A. F.: Diseases of the Knee, *Philadelphia, Lippincott*)

of severity, and I believe all the usual causes for inflammation of any bursa. Most of the acute cases that I have seen have resulted from a minor twisting trauma, particularly of tibial external rotation, which may have loosened bursal allegiance to the ligament. Often, the symptoms simulate an internal derangement of the knee with an apparent locking or lack of freedom of extension. DePalma emphasized that "in extension all portions of the tibial collateral ligaments are tense" but also that "throughout the entire arc of flexion some portion of the ligament is taut . . .; even in extreme flexion the long anterior superficial fibers are still taut." From the symptomatology I believe that this anatomy is important Often the patient will not fully extend, because, by keeping the knee in flexion, the taut anterior superficial fibers are not really pressing against the bursa now just anterior to them. Snap extension of the knee or external rotation of the flexed knee with finger on the often rounded, tender point will roll these front ligament fibers onto the bursa, which is, after all, a bumper backed up by the meniscus. Disability often is rather distinct; sometimes the patient appears on crutches or with a cane, having been prepared by the referring general practitioner for surgical removal of the meniscus. At times an injection of only 1 or 2 cc. of 1 per cent procaine plus hydrocortisone has produced such dramatic cure that the patient believes that a minor miracle has taken place.

In either degenerative or rheumatoid knee arthritis, as well as in traumatic inflammation, separate injection of this bursa from the knee joint itself, if indicated by local findings, may make the difference between success and failure. Miller, White and Norton,* of Glasgow, Scotland, demonstrated both subjective and objective improvement in up to 86 per cent of hypertrophic arthritic knees injected by *placebo* technic. Possibly this addition can get us closer to 100 per cent. Underlying degenerative changes may exist in the medial meniscus, and often the bursitis is only symptomatic evidence of the osteoarthritis, as in Baker's cyst, and meniscectomy probably is indicated occasionally. On a few occasions this bursa has been demonstrated at arthrotomy. There is an inflamed and thickened ill-defined sac or fibromatous nodule with a nonspecific inflammatory bursal diagnosis from the laboratory. Frequently there is a flatfoot position with its lower leg external rotation strain tending to exist in gait, and knock-knee seems to be much more common than bowleg. Thomas heel with inner heel wedge is of considerable value and, of course, other physical therapy in many cases.

In at least a dozen cases of torn medial meniscus with a locked knee that I expected to remain locked I have seen all symptoms disappear in a few moments from a few cubic centimeters of procaine.

* Miller, J. H., White, John, and Norton, T. H : The value of intra-articular injections in osteoarthritis of the knee, J. Bone & Joint Surg. 40-B:636-643, 1958.

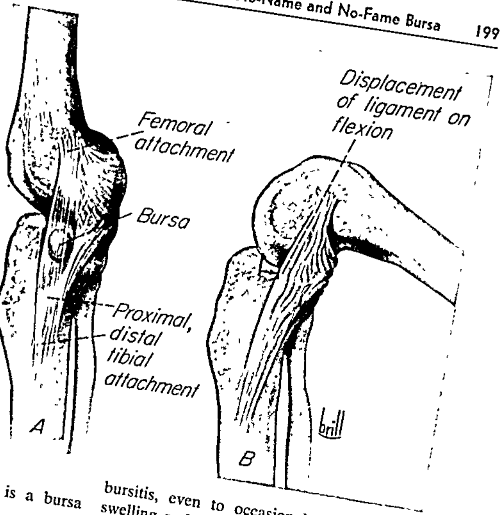

FIG. 2. Tibial collateral ligament. (A) Note that its posterior oblique fibers blend with the periphery of the meniscus at the level of the joint posterior to the middle of the ligament. Frequently, a bursa is encountered between the meniscus and the anterior portion of the superficial layer of the ligament. (B) In flexion the posterior fibers relax; however, even in complete flexion some of the anterior vertical fibers are still taut. Also, in flexion the ligament as a whole shifts backward. (DePalma, A. F.: Diseases of the Knee, Philadelphia, Lippincott)

To sum up:

1. DePalma says that there is a bursa there (94%).

2. It behaves as bursae do when ill and reacts to treatment commonly effective in bursitis, even to occasional local rounded swelling and fluid return on procaine injection: therefore, clinically it is a bursitis.

3. In lieu of a better name for it, the author calls it the no-name bursa.

Le Bursa sin Nomine e sin Renomine

Summario in Interlingua

Il pare que un bursa existe—e es clinicamente irritabile—al semper tense margine anterior del ligamento collaterial mediotibial del genu, inter le ligamento mesme e le menisco. Illo es satis frequentemente le sito de gravamines con que le patiente se presenta al sala de consulta. Illo non pare haber essite discutite detaliatemente in le litteratura, e illo non ha un nomine a parte le designation "bursa sub le ligamento collateral medio-tibial." Illo es un de tres o quatro que on trova mentionate como existente in le un o le altere sito sub le ligamento. In rotation externe del gamba inferior con respecto al femore in certe statos de flexion, le bursa—quando irritate per un del causas ordinari de bursitis—evoca dolores que frequentemente non pote esser localisate precisemente per le patiente. Il pote esser constatate un puncto local de sensibilitate e a vices un rotunde e palpabile amplor que es capace de glissar inter le menisco e le margine anterior del ligamento quando un tal existe. Illo pote occurrer como parte del processo pathologic de osteoarthritis o de arthritis rheumatoide del genu. In tal casos illo pote causar symptomas continue in le genu si illo non es tractate separatemente como phenomeno local. Illo responde a injectiones de procaina e hydrocortisona, a physiotherapia, o a chirurgia. In isto, illo non differe de altere bursitides.

Section III

ITEMS

20

Congenital Absence of Femur and Fibula

Report of Two Cases

ROBERT B. ACKER, M.D.*

Congenital deformities of the leg are multiform, and almost any pattern may be encountered. Total absence of the femur and the fibula is a pattern that is not common. Two cases of this unusual developmental anomaly are reported here.

CLINICAL DESCRIPTION

Case 1. A Negro female child first seen at 2 years of age. An otherwise healthy child with a congenital defect of the right leg. Roentgenographic examination disclosed complete absence of the femur and the fibula, the upper end of the tibia occupying a position in proximity to the acetabulum but not forming a joint. There was indication of a fairly well-formed acetabulum Later, a center of ossification appeared in the hip area, and, as the child grew and bore weight, this center developed into a recognizable head and neck of the femur, the head articulating with the acetabulum and the acetabulum showing more development. The right leg extended as far as the knee of the opposite leg and was movable in all directions but not with the same range as a normal hip. The leg was reasonably stable, there being some lateral thrust when weight was borne. The foot was of normal contour and functioned well

Case 2. A white male child first seen at 3 years of age. An available roentgenogram made when he was 3 months old showed a congenital deformity very similar to that of Case 1. There was a complete absence of the femur and the fibula, the upper end of the tibia being below the acetabulum area and not contacting it. In this case the acetabulum was not developed.

A center of ossification was seen in this early roentgenogram, above the proximal end of the tibia, which center later developed into a segment of bone of no specific contour. There is no direct resemblance of this fragment to femoral condyles or femoral neck, but most likely it represents femoral condyle area. Placement of this bone has a tendency to stabilize the hip area more than before. The foot accompanying this short tibial leg possessed all its components but was a marked clubfoot of the equinovarus type. It became necessary to correct the position by wedging in plaster before the prosthesis could be fitted. The deformed leg was freely movable in all directions, but, as in Case 1, the range of motion was not normal.

COMMENTS

Before a prosthesis was fitted in these cases, the favorite means of locomotion was by bearing weight on the foot of the short leg and the knee of the normal leg, thus equalizing the weight distribution.

The problem was to supply a suitable prosthesis so designed that sacrifice of any part of the short leg was not necessary, and the foot, a fairly good one, could be used comfortably to assist in weight-bearing and balance. Amputation of the foot, if it seems to be necessary, should be deferred until full skeletal growth has been accomplished. We find the short leg with foot attached to be a

* South Bend, Ind.

very desirable *stump,* free of pressure or abrasion, and comfortable, with weight-bearing at its end. It supplies the prosthesis with more power and easier mobility than a short stump. The chief handicap, with the foot in place, is to devise a workable *knee bend.*

The two main difficulties in function of such a prosthesis are:

1. The problem of a loose *joining* in the hip region, not a true joint; consequently, a unstable point of body support with sid thrust.

2. The problem of the foot, which is a important asset in stabilizing and controllin the prosthesis. On the other hand, it is un sightly cosmetically, especially in a femal and adds a difficulty in locating a satisfac tory knee-joint bend. However, it is though

FIGS 1 and 2, Case 1. FIG. 1. (*Left*) Roentgenogram of the pelvis and the legs taken at 1 year of age. The fibula is completely absent, and the tibia is smaller than in the normal leg The ankle and the foot are normal A center of ossification, above the tibial epiphysis, is the only representation of the absent femur. The tibia does not form a joint with the pelvis The acetabulum shows fair development. (*Right*) Roentgenogram at 7 years of age. A rudimentary head and neck of the femur have now appeared, developing from a center of ossification that developed after the initial roentgenogram was made (*left*) The acetabulum is deep and contains the head of the femur. The initial center of ossification above the epiphysis of the tibia has developed into a bone mass that probably represents the condylar area of the femur. It has no definite structure, and there is no connection between the neck of the femur and this bone mass.

that when adult stature is reached, the foot on the short leg will be on the level or above that of the knee of the normal leg, thus solving the proper location of a knee bend in future prosthesis.

The initial prosthesis (Fig. 5, *bottom, left*) consisted of a pelvic band—a laced leather cuff enclosing the leg and a shoe for the foot, riveted to a metal plate attached to the side bars. Below this, a contoured artificial leg and foot were attached with a second shoe for weight-bearing. In Case 2, the foot was in equinovarus and was wedged in plaster for better fitting in the shoe. The children learned to walk and balance well with these appliances.

At 6 years of age a better-proportioned, neater and improved fitting prosthesis was supplied: in Case 1, without bend; in Case 2, a bend below the foot. These are now being

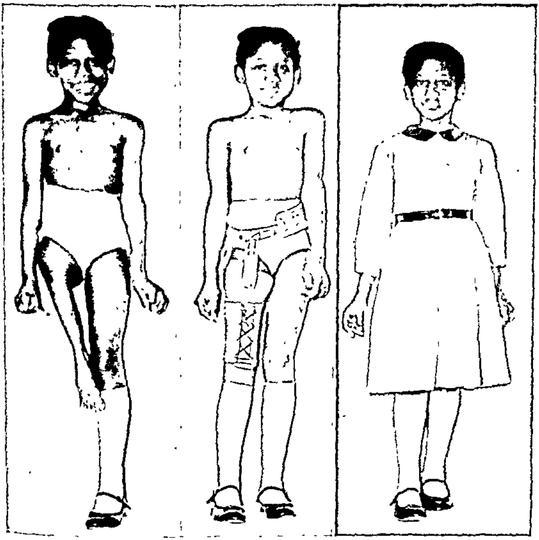

FIG. 2. (*Left*) Congenital absence of femur and fibula The deformed leg has a normal foot and ankle joint It is smaller and less muscular than the lower extremity in the normal leg Knee and hip joints are absent. Otherwise, the child is well developed and active (*Center*) The second type of prosthesis furnished this girl—a well-contoured, nicely fitting apparatus that gives good support. It is tolerated well. (*Right*) With clothes, the prosthesis is scarcely noticeable. She is a normal, healthy youngster and participates in most activities.

FIGS. 3 to 5, Case 2. FIG. 3. Roentgenogram made at age of 3 months. The left side appears as the right here. The absence of the femur and the fibula is apparent. The foot is in equinovarus position. The pelvis is relatively well developed. The *acetabulum is very shallow on the de*formed side. There is no hip or knee joint.

FIG. 4. Roentgenogram at 7 years of age. The left side of the pelvis is not as fully developed as the right side. On the left, the epiphyseal line between the ilium and the pubis and the ischium is open, and the inferior rami of pubis and ischium are not joined. The acetabulum is fairly deep but is not normal in contour. A bone mass has appeared at the upper end of the tibia. It is difficult to evaluate this It may represent tibial epiphysis or condylar area of the femur.

tested. In both cases the foot was wedged into equinus for better position before applying the last prosthesis.

SUMMARY

Congenital absence of both femur and fibula is a relatively rare condition. Search of the literature disclosed its rarity: references to this particular anomaly were meager. Doctors should be encouraged to report congenital anomalies. Such reports are desirable; they would serve as a valid basis for statistical study.

FIG. 5 (*Top, left*) The relationship of the deformed left leg is well shown here. It is about one half the length of the normal leg as measured from the anterior superior spine to the internal malleolus. Except for the left extremity, the boy was normal physically and quite active (*Top, right*) This is the position that this child, as well as the one depicted in Figures 1 and 2, assumed in walking before prostheses were supplied (*Bottom, left*) The initial prosthesis, described in this chapter, with which Cases 1 and 2 were fitted. They learned to balance and walk quite we[illegible] (*Bottom, right*) The second type of prosthesis with which Case 2 [illegible] from the apparatus supplied Case 1 The leg is [illegible] foot has been wedged in equinus and a knee lock put in below the foot with a wire cable release

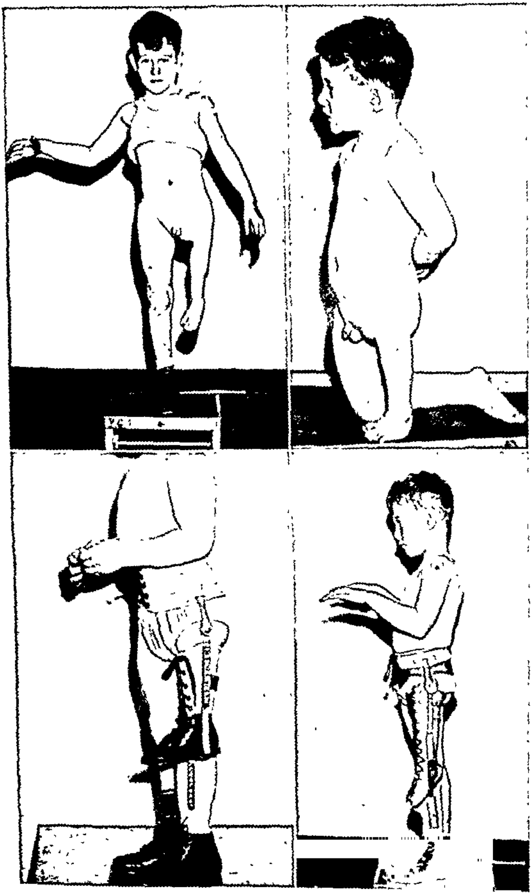

FIGURE 5 (*Caption on facing page*)

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Spondylolysis Following Spinal Fusion

Report of a Case

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This chapter deals with a case of spondylolysis implicating the neural arches of the fourth lumbar vertebra following a spinal fusion from the fourth lumbar vertebra to the sacrum The fusion was performed for symptomatic spondylolisthesis in a female 52 years of age. Only two other similar cases were found in the literature. Unander-Scharin[12] recorded the first case in 1950. He designated the lesion *spondylolisthesis acquisita.* In this instance, a defect appeared in the neural arches of the third lumbar vertebra six years after a spinal fusion from the third lumbar to the first sacral vertebra. The second case was reported by Anderson[1] in 1956; lysis of the neural arches of the fourth lumbar vertebra occurred following fusion between the fifth lumbar and the first sacral vertebrae. The prime reason for recording our case is to focus the attention of the orthopaedic surgeon on another factor that may be responsible for pain and nerve-root irritation following fusion of two or more vertebral elements of the lumbosacral region.

CASE REPORT

The patient, a female, 52 years of age, was admitted to the Jefferson Medical College Hospital on August 24, 1955, with the chief complaint of low-back pain of two years' duration that radiated into the posterior aspects of both lower extremities as far as the calves. At first the pain was intermittent in nature, but for the past year it had been more or less constant. Nothing in the history of injury accounted for the symptoms.

Physical examination revealed pronounced paravertebral muscle spasm in the lumbar region. Motion in the lumbar spine was restricted approximately 60 per cent in all directions. Pressure over the spinous processes of the fifth lumbar and the first sacral vertebrae elicited severe tenderness.

The neurologic examination was essentially negative.

Roentgenographic examination disclosed a large defect in both pedicles of the fifth lumbar vertebra with forward migration of the body of the fifth lumbar vertebra on the body of the first sacral vertebra.

On August 26, 2 days after admission, the lumbosacral region was explored. The large defects in the neural arch of the fifth lumbar vertebra were clearly visualized. A classic Hibbs' type spinal fusion was performed from the fourth lumbar vertebra to the sacrum The fusion was reinforced by an H bone graft spanning the interval from the spinous processes of fourth lumbar and first sacral vertebrae. Cancellous bone chips were added; these were obtained from the anterior iliac crest Ten days after the operation, a plaster cast that extended from the axillae to the knee was applied; the cast was worn for 12 weeks After removal of the cast, a Knights-Taylor brace was applied and was worn for a period of 4 months

The patient made an uneventful recovery, and 6 months after the operation had returned completely to normal She was free of all pain and was able to perform all her household duties. She was observed at 6-month intervals, and in August, 1957, 2 years after operation, was discharged. At this time roentgenographic studies

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FIG. 1. Roentgenogram taken 2 years postoperatively shows a solid bony fusion There is no evidence of a defect in the neural arch of the fourth lumbar vertebra

FIG. 2. Roentgenogram taken 10 months after discharge discloses an intact fusion, but a defect was noted in the pedicles of the fourth lumbar vertebra.

revealed a solid, mature bony fusion from the fourth lumbar to the first sacral vertebra (Fig 1).

Approximately 10 months after discharge (June, 1958) the patient developed some pain in the lumbar area that radiated to the right sacro-iliac region Roentgenographic studies at this time disclosed an intact fusion, but a defect was noted in the pedicles of the fourth lumbar vertebra (Fig 2) The usual conservative measures were instituted, including bed rest, traction and the wearing of a brace, but the pain became progressively worse and unbearable. The patient was admitted to the Jefferson Medical College Hospital on July 11, 1958, for exploration of the fusion area.

The posterior bony fusion from the fourth lumbar vertebra to the sacrum was intact. After exposing the zygapophysial joints between the third and the fourth lumbar vertebrae, pressure on the fusion mass readily demonstrated a bilateral defect through the pars interarticularis of the neural arch of the fourth lumbar vertebra. It became apparent that lysis of the neural arch had occurred after the first operation. The fusion was extended upward to include the third lumbar vertebra; the raw, bony bed was reinforced by cancellous bone chips. The patient's postoperative course was uneventful. When last seen, 10 months after the second operation, she was free of all pain and had resumed all activities. Roentgenographic studies revealed a solid bony fusion from the third lumbar to the first sacral vertebra (Fig 3).

DISCUSSION

Much clinical evidence has been assembled to support the premise that spondylolysis is the result of deranged mechanics of the affected portion of the spine, permitting the implicated isthmus to be pinched between the inferior articular process of the

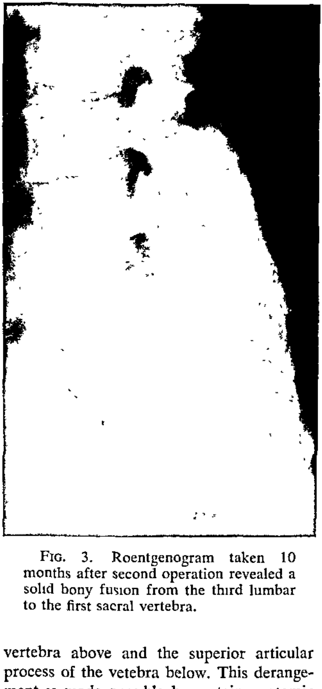

FIG. 3. Roentgenogram taken 10 months after second operation revealed a solid bony fusion from the third lumbar to the first sacral vertebra.

vertebra above and the superior articular process of the vetebra below. This derangement is made possible by certain anatomic abnormalities present in the affected region. Hilel Nathan,[11] in a recent investigation, clearly illustrates these anatomic peculiarities, which he designates as predisposing or conditioning anatomic factors. He recorded that pinching of the isthmus was not possible when (1) both the superior process of the vertebra below and the inferior process of the vertebra above were relatively short; (2) the vertebral bodies were relatively tall and their distal surfaces impinged on each other; (3) relatively large spinous processes of the fourth and the fifth lumbar vertebrae made contact and, similarly, the spinous process of the fifth lumbar vertebra rested on a relatively large sacral spinous tubercle; (4) relatively large transverse processes of the fifth lumbar vertebra rested on the alae of the sacrum; (5) the roots of the transverse processes of the fourth lumbar vertebrae rested on well-developed laterally projecting upper posts of the superior articular processes of the fifth lumbar vertebra. On the other hand, the aforementioned features of the vertebrae may be so altered in spondylolytic spines that the articular processes above and below the implicated vertebra are free to approach and compress the isthmus. This intimate relationship between the cleft in the isthmus and the articular processes above and below was also observed by Lane[9] in 1885 and Meyer[10] in 1931 in cadavers with spondylolisthesis. Both these workers were of the opinion that the defect *in the neural arch was the direct result* of the compression of the isthmus by the articular processes above and below.

Repeated trauma to the isthmus by the pincer effect of the articular processes above and below must produce local vascular changes, which eventually result in dissolution of the bony elements. The resulting defect then is occupied by fibrous tissue. Brandt[4] described such a process occurring in "creeping fractures," and Henschel[8] recorded these same alterations in the formation of "exhaustive fractures."

Once the defect has formed in the isthmus, bone repair does not occur. This can be readily explained by (1) the presence of the shearing stresses, which tend to displace the detached vertebral body forward, (2) the hypermobility of the neural arches, which precludes bone formation; and (3) the continuance of the pincer-effect mechanism on the isthmus, which was primarily responsible for the dissolution of the bone

In anatomically predisposed spines, lysis of the isthmus may be enhanced by certain

contributory factors that tend to reduce the height of the intervertebral disks, to increase the lumbar lordosis and to approximate the neural arches of the vertebrae. These circumstances will readily permit the pincer-effect mechanism to work on the vulnerable isthmus. Some of the factors are trauma, erect posture, lifting and carrying heavy weights, and advancing age.

It is now generally accepted that spondylolysis is not the result of a congenital defect in the development of the neural arch.[3,5] The lesion is indeed rare in fetuses or still-born infants,[2,3] and rare in children.[5,7]

In the case reported here the defect in the neural arch of the fourth lumbar cannot be explained on the aforementioned pincer mechanism. Careful study of the roentgenograms reveal that the superior processes of the fifth lumbar vertebra are fused solidly to the inferior processes of the fourth and that the inferior processes of the third lumbar do not impinge on isthmuses of the neural arch of the fourth lumbar vertebra. These observations were readily confirmed at operation. On the other hand, one must admit that the line of stress in the erect position in this lordotic spine has shifted, following the spine fusion, so that now it passes through the neural arch of the fourth lumbar vertebra. As previously noted, repeated trauma of this nature may readily precipitate vascular change in the neural arch, which terminates in dissolution of its bony elements and the formation of clefts in its isthmus.

Because of the paucity of reports in the literature of spondylolysis following spinal fusion, one must assume that mechanical derangements, such as an increased lordosis, as noted in this case, are not encountered frequently. However, in light of the frequency of unexplained pain following spinal fusions, it may well be that spondylolysis is overlooked often.

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